AN ABSTRACT OF THE THESIS OF

FREDRICK JOHN GUNTHER for the DOCTOR OF PHILOSOPHY
(Name) (Degree)

in OCEANOGRAPHY presented on Oct 28, 1971
(Major) (Date)

Title: STATISTICAL FORAMINIFERAL ECOLOGY FROM SEASONAL SAMPLES, CENTRAL OREGON CONTINENTAL SHELF

Abstract approved: Redacted for Privacy
Gerald A. Fowler

This study examined the foraminifera and the ecologic conditions of the benthic environment of the Oregon shelf and the uppermost slope (75-550 m depth) between 143°45' N and 144°40' N. Seasonal collections monitored the near-bottom marine environment and the sedimentary substrate at 16 stations. The foraminiferal benthic fauna was examined from eight seasonal stations and two additional stations. Use of a multiple corer provided randomly selected subsamples of the sediment for ecologic and faunal analyses. Use of water bottles that triggered upon bottom impact provided measurements of the water as close to the bottom as 0.6 m. Computerized data processing and statistical analyses aided the ecologic and faunal evaluations.

The environmental study showed the existence of considerable variation in the hydrography of near-bottom waters, especially between summer and winter (upwelling and non-upwelling) collections at the same station. Upwelling conditions directly affect the benthic

environment. In addition, the water at any one place, at least during upwelling, was so well mixed that vertical stratification did not exist between 0.6 and 5.0 m off the bottom. Statistically significant seasonal variations in surface sediments at the same station were not observed.

The living benthic foraminiferal fauna exhibited considerable within-station variation both in species composition and in specimen size of selected species. The percent abundance of individual dominant species varied in adjacent cores (subsamples) by amounts up to 46%. Living specimens of a single species were found that were three times as large as the smallest living specimen from the same sample, yet there was no evidence of a multimodal size distribution resulting from age classes.

The author suggests that the dominant species are aggregated and that the aggregations are colonies of asexually produced siblings. Lack of fit of species-frequency curves to the lognormal distribution indicated that relatively few species are fit to reproduce in a particular environment; most juvenile specimens that enter a particular environment belong to species that will not thrive there and either die or simply maintain growth with little chance of reproductive success.

The existence of colonial aggregations of individuals is considered to provide the best explanation of the observed variations between adjacent samples. However, the observed variations could be due to sampling error or to substrate microheterogeneity.

A possible natural community of 15 dominant species has been determined for those species that form a consistent part of each other's biologic environment. The community crossed the depth and substrate boundaries upon which the stations were selected and appeared to be a general community for the Oregon outer shelf. The limits of the community appear to be determined mostly by water depth, with approximate boundaries at 75-100 m and somewhere between 200-500 m.

Regression analyses to determine the ecologic control on the foraminiferal fauna did not indicate a close correspondence between faunal parameters and environmental variables.

Regression analyses to determine the ecologic control on individual species indicated that most species depended upon a set of two to four environmental variables rather than upon one single limiting factor. The set for each species was different. Temperature, phosphate concentration and oxygen concentrations were common hydrographic members of sets; percent silt, percent sand, percent clay, organic carbon content and organic nitrogen were common sedimentary members of sets.

Statistical Foraminiferal Ecology frôm Seasonal Samples, Central Oregon Continental Shelf

by

Fredrick John Gunther

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

June 1972

APPROVED:

Redacted for Privacy

Assistant Professor of Oceanography
in charge of major

Redacted for Privacy

Chairman of Department of Oceanography

Redacted for Privacy

Dean of Graduate School

Date thesis is presented October 28, 1971

Typed by Mary Jo Stratton for Fredrick John Gunther

ACKNOWLEDGMENTS

I would like to thank my major professor, Dr. G. A. Fowler, for his considerable patience, advice and support. Numerous students and staff have been of assistance to the author, both in discussing the project and in aiding its operation. Special thanks are due to Drs. A. G. Carey, W. G. Pearcy and Gerry Bertrand for assistance in formulating the project, collecting the samples and evaluating the results. Thanks also are due to the Master and crew of the R/V CAYUSE for the benefits of their help and experience at sea. My wife, Barbara Gunther, was most helpful with the editing. Most of the drafting was done by Natasa Sotiropoulos. The Chemistry Section of the Department of Oceanography processed numerous hydro samples and the Sediment Lab processed just as numerous sediment cores. Much valuable assistance in debugging the computer programs was freely given by Jim Meeker and Ken Keeling. Valuable assistance on the cruises has been given by David Stein, Rob Buehrig, Mike Kyte, Charles Culberson, Larry Helm, Pete Kalk, Gorden Ness, Bob Roush, Joe Spigai, Gary Muelhberg, and many others.

The study was supported by the National Oceanic and Atmospheric Administration (maintained by the U.S. Department of Commerce) institutional Sea Grant 2-5187.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

STATISTICAL FORAMINIFERAL ECOLOGY FROM SEASONAL SAMPLES, CENTRAL OREGON CONTINENTAL SHELF

INTRODUCTION

This study was designed to evaluate the influences of sediment type and water properties on the living foraminiferal faunas of the central Oregon shelf and uppermost slope. It is one part of the Sea Grant Benthic Environment Project, which uses seasonal collections, simultaneous collections of sediment, water and biologic samples, replicate samples and statistical evaluations to study the environment and faunas off the Oregon coast.

This investigation differs from previous seasonal studies of Foraminifera in that it examines an open shelf environment. Meyer's (1942) seasonal study was based upon samples from littoral tide pools and shallow (5-7 meters) sublittoral sands. Walton's (1955) seasonal study used samples from a single traverse in a protected embayment. The seasonal study by Phleger and Lankford (1957) was conducted entirely within sheltered bays, as were those of Hunger (1966), Brooks (1967), Manske (1968) and Haman (1969). Reiter's (1959) collections were taken from the beach sands of the intertidal zone. Boltovskoy and Lena's (1969a) study was based upon weekly-collected samples from an estuary.

The present project may be considered an extension of that of Boettcher (1967). His study of the faunas from three traverses on the central Oregon shelf established the existence of four assemblages over different sections of the depth gradient. Sediment information from the same area (Runge, 1966) showed considerable variation in the substrate. Taking advantage of this variation, stations were selected for seasonal sampling that would allow the comparison of different substrates at the same depth and of the same substrates at different depths (Figures 1 and 2).

Location

The Sea Grant Benthic Environment study area is located on the central Oregon continental shelf, with one station on the uppermost continental slope. The shelf off the state of Oregon is characteristically narrower, steeper and with a deeper outer edge than the average continental shelf (Byrne, 1962a). Within the study area, the Oregon continental shelf achieves its maximum width of 65 km (40 miles) (at 44° 12.7' N) and just south of the study area it reaches its minimum width of 24 km (15 miles) (at 43° 30.0' N). The shelf slope varies locally from 0° 09' to 0° 22', being steeper at the narrowest part of the shelf. The water depth of the outer edge of the shelf also varies locally, from 150 to 175 meters. Major topographic highs on the shelf are Stonewall Bank, with 64 m (210 feet) of relief, and Heceta

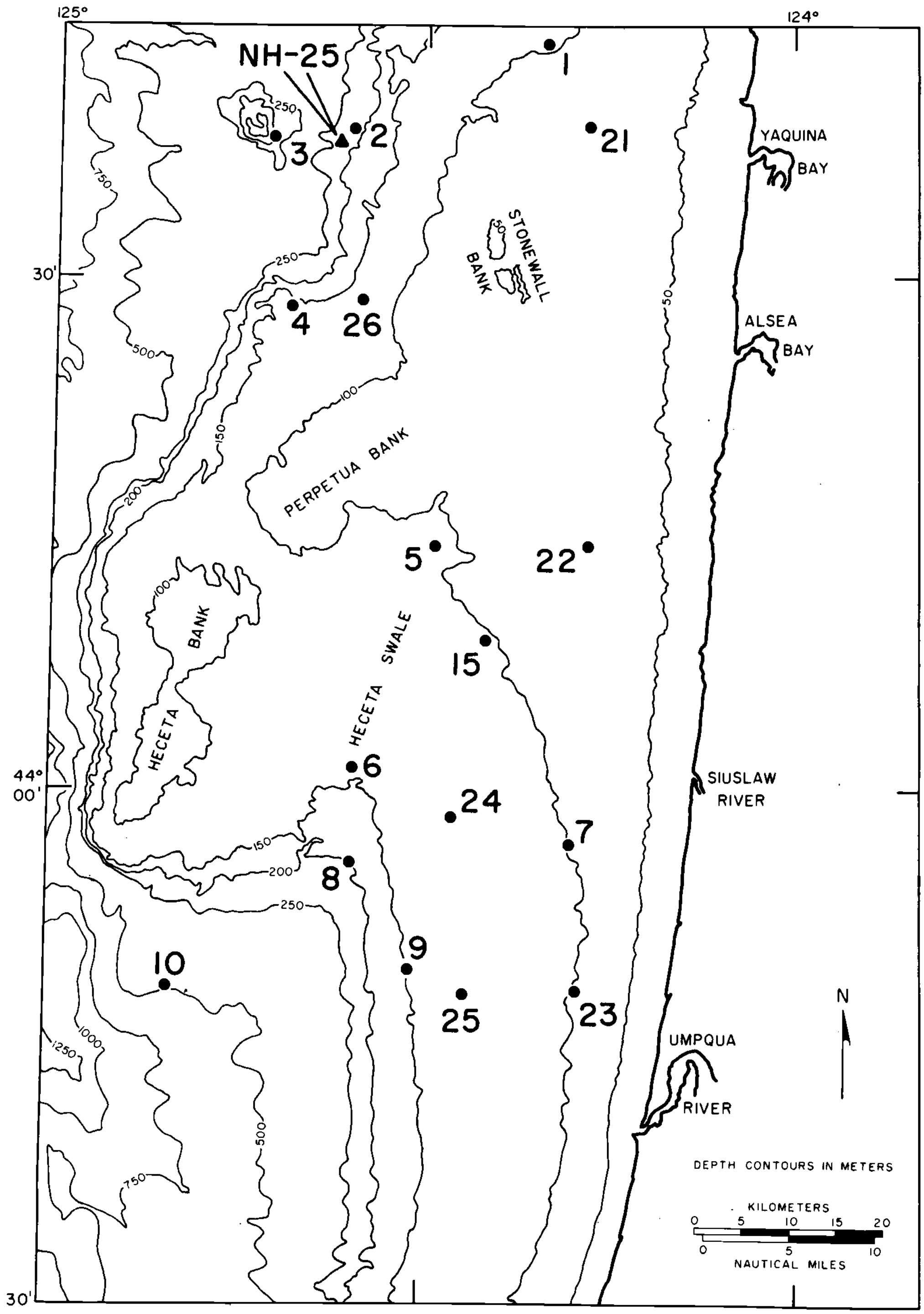

Figure 1. Bathymetric features and Sea Grant seasonal stations on the central Oregon shelf. The location of hydrographic station NH-25 is also given.

DEPTH CLASS

SEDIMENT CLASS	1 (75m)	2 (100m)	3 (125m)	4 (150 m)	5 (200m)	6 (500m)
1 (to 20%)				6	8	
2 (20%–60%)		23	25		3	
3 (60%–75%)		7	24	9	2	
4 (75%–100% SAND)	22	15	26	4		10

Figure 2. Sea Grant Benthic Environment Project stations sorted into classes by depth and sediment type. Sediment type based upon weight-percent sand.

Bank with 73 m (240 feet) of relief (Byrne, 1962a, b). Collecting stations are located both north and south of the banks.

General Sediment Pattern

The sediments of the shelf and uppermost slope off Oregon form three broad but irregular bands more or less parallel to the coast (Figure 3). The innermost band is the present and former beach sands, generally with a high quartz content, but also with local concentrations of glauconite, magnetite, gold and other heavy minerals (Kulm et al., 1968). The next band seaward is admixed sands and muds. In the vicinity of headlands and underwater banks, this band may be missing. It also may be missing or restricted near mouths of rivers, where terrestrial silts and clays are brought to the ocean in large quantities. Farther seaward is a general band of mud, interrupted occasionally by glauconitic sands on bathymetric highs, or by rocky outcrops (Byrne and Panshin, 1968).

General Hydrography

The sea water overlying the central Oregon continental shelf has been derived from the Subarctic Pacific Water of the southern branch of the Aleutian Current (Sverdrup, Johnson and Fleming, 1942) under the modifying influences of rainfall, runoff, upwelling and the Columbia River effluent (Pattullo and Denner, 1965). According

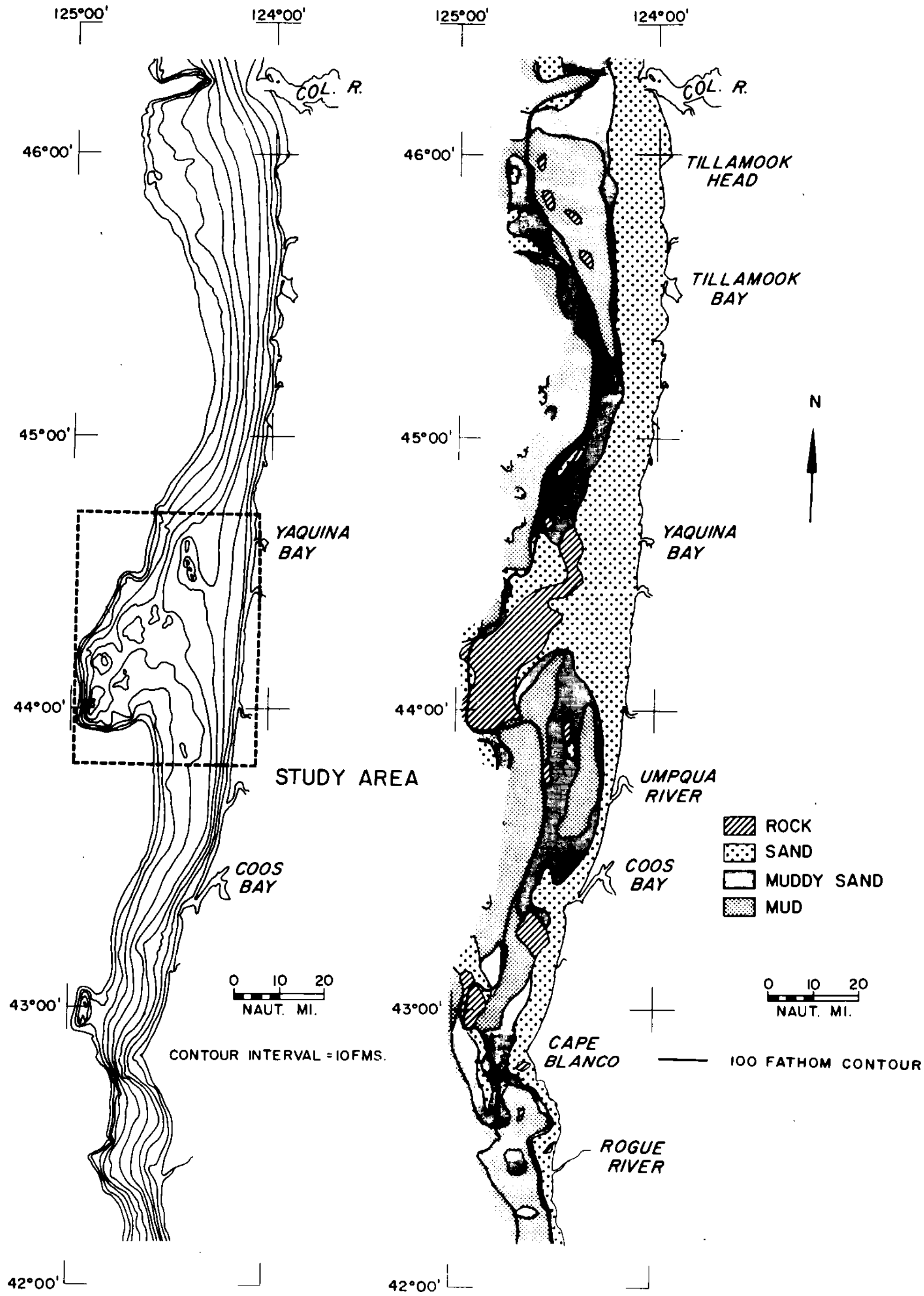

Figure 3. Distribution of major sediment types on the Oregon shelf; bathymetry in fathoms given for reference. Sea Grant Benthic Environment study area indicated. From Byrne and Panshin (1968) after data in Runge (1966).

to the classification of Tully (1964, p. 954), it belongs to the Coastal Domain of the water transitional between Subarctic Water and Subtropical Water.

Seasonal changes in the shelf surface waters have been widely recognized. Drift bottle studies of surface currents (Burt and Wyatt, 1964) showed seasonal changes from the winter (October-March) northward-flowing Davidson Current to the summer (June-August) southward-flowing California Current, with much variation in current direction and strength during spring (April-May) and fall (September). The prevailing direction of onshore sea and swell changes from predominantly southwestern in the winter to predominantly northwestern in the summer (Kulm and Byrne, 1966). Continental Shelf currents change from a southerly flow at 21 cm/s (20 m depth) and 13 cm/s (60 m) during the summer to a northerly flow of 16 cm/s (20 m) during the winter (Collins, 1967). Depth and surface distributions of alkalinity, specific alkalinity (Park, 1968), salinity, pH, oxygen concentration and inorganic phosphate concentration (Park, Pattullo and Wyatt, 1962) also change seasonally.

Seasonal Changes

The monsoonal weather pattern of the Oregon coast (Kulm and Byrne, 1966, p. 89) is reflected not only in the surface waters of the shelf, but also in deeper waters. The hydrographic portion of the benthic environment exhibits a consistent pattern of seasonal changes. If we examine individual water properties at discrete depths at one place (Newport Hydrographic line, station 25) for the period from January 1, 1962, to December 31, 1969 (data from Wyatt and Gilbert, 1967; Barstow et al., 1968; Barstow, Gilbert and Wyatt, 1969a, b; Wyatt et al., 1967, 1970), we find seasonal variations, not only for the conservative water properties (Figure 4) but also for those that change with biologic activity (Figure 5).

Statistical tests confirmed the visual impression of a regular seasonal pattern to the variations (Table 1). As expected, shallower waters showed a greater seasonal component of variation, but even at 200 m, the water has more than 50% of the variability in temperature statistically explained by seasonality. We can therefore expect that the seasonal cycles of change are important for members of the continental shelf benthic community.

In addition to seasonality, the seven-year data set showed the existence of catastrophic events. Temperature and salinity curves record waters with abnormally low salinity and high temperature invading depths much greater than normal (below 75 m). Whether this invasion was caused by extreme cooling (adiabatic mixing), by high and prolonged winds (turbulent mixing) or by a gross shift in ocean current patterns is not apparent from the hydrographic data. In

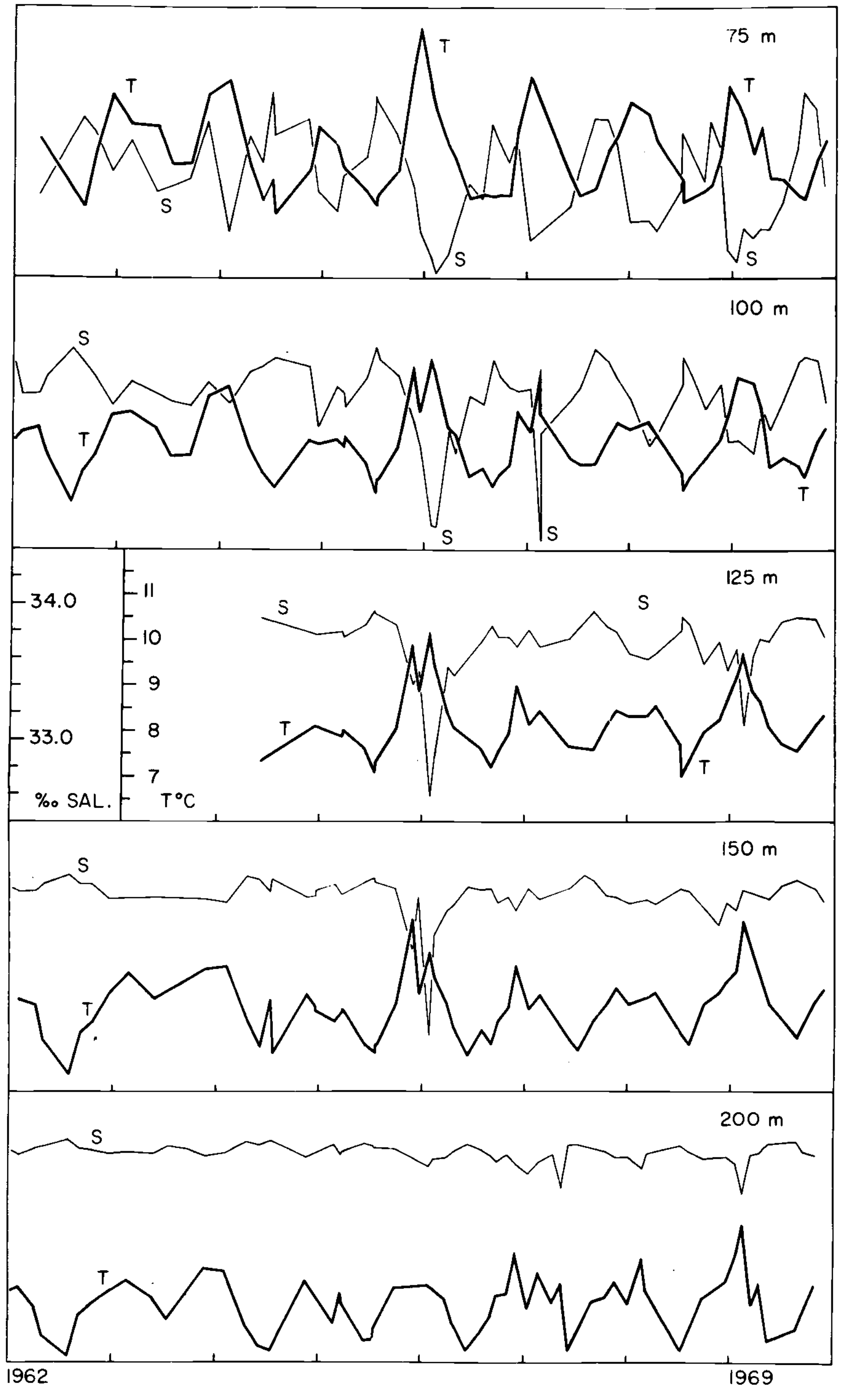

Figure 4. Seasonal variation in conservative water properties, NH-25.

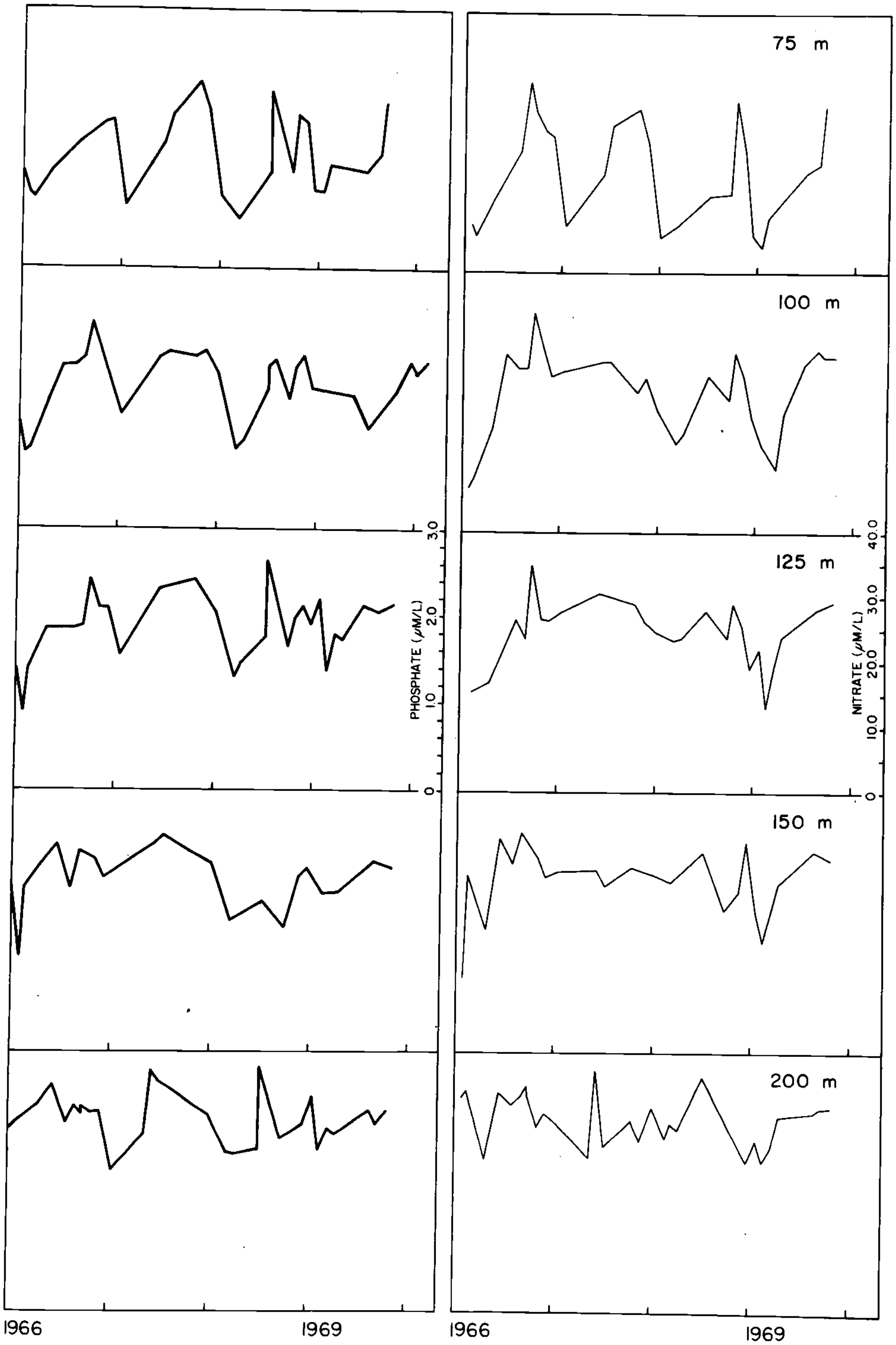

Figure 5. Seasonal properties in non-conservative water properties, NH-25.

Table 1. Statistical analysis of standard water properties for seasonal variation, NH-25 data, 1962-1969. The independent variable (X) is the day of the year in radians.

Dependent variable	Depth (m)	Step	R^2 (%)	Regression equation
Temperature	75	2	72.54	$Y = 8.775 + 0.401 \cdot SIN(X) + 0.97 \cdot COS(X)$
	150	2	58.51	$7.791 + 0.0763 \cdot SIN(X) + 0.711 \cdot COS(X)$
	200	3	53.56	$7.217 + 0.0364 \cdot X + 0.023 \cdot SIN(X) + 0.638 \cdot COS(X)$
Salinity	75	3	51.20	$Y = 33.151 - 0.558 \cdot SIN(X) - 0.1851 \cdot COS(X) + 0.334 \cdot (SIN(X))^3$
	200	3	25.26	$33.936 - 0.0272 \cdot SIN(X) - 0.06 \cdot COS(X) + 0.0338 \cdot (SIN(X))^3$
Phosphate	75	3	49.76	$Y = 1.188 + 0.0752 \cdot X - 0.222 \cdot SIN(X) - 0.231 \cdot COS(X)$
	100	3	52.05	$1.69 - 0.68 \cdot SIN(X) - 0.231 \cdot COS(X) + 0.445 \cdot (SIN(X))^3$
	125	3	39.83	$1.75 + 0.055 \cdot X - 0.152 \cdot SIN(X) - 0.17 \cdot COS(X)$
	150	3	25.60	$1.89 + 0.0664 \cdot X - 0.184 \cdot SIN(X) + 0.119 \cdot (SIN(X))^3$
	200	3	19.84	$2.25 + 0.064 \cdot SIN(X) - 0.177 \cdot COS(X) - 0.134 \cdot (SIN(X))^3$

any event, such an invasion must have had considerable effect on the benthic community.

Upwelling

The seasonal changes in the water are related to the seasonal change in local wind direction and strength (Burt and Wyatt, 1964; Collins, 1967). Coastal upwelling begins in the spring with a shift from a predominantly southern to predominantly northern wind (Smith, Pattullo and Lane, 1966). The northerly winds cause Ekman transport of surface waters offshore, necessitating replacement inshore by waters normally at 100-200 m depth (Pattullo and McAlister, 1962; Smith, 1967), until the irregular wind patterns of the fall permit warm surface waters to move inshore (Pattullo and McAlister, 1962) and the Davidson Current to flow northward (Pattullo and Burt, 1962; Burt and Wyatt, 1964).

Hydrographic profiles taken across and near the study area in 1968, 1969 and 1970 show interesting variations in the general upwelling pattern. Large volumes of oxygen-deficient water occur within Heceta Swale (Figure 6) and shoreward of Stonewall Bank. Profiles parallel to the coast show two large volumes of oxygen-deficient water near-shore, behind Stonewall Bank and off Depoe Bay, separated by water with higher levels of oxygen off Yaquina Bay (data in Barstow, Gilbert and Wyatt, 1969; Thomlinson, 1971).

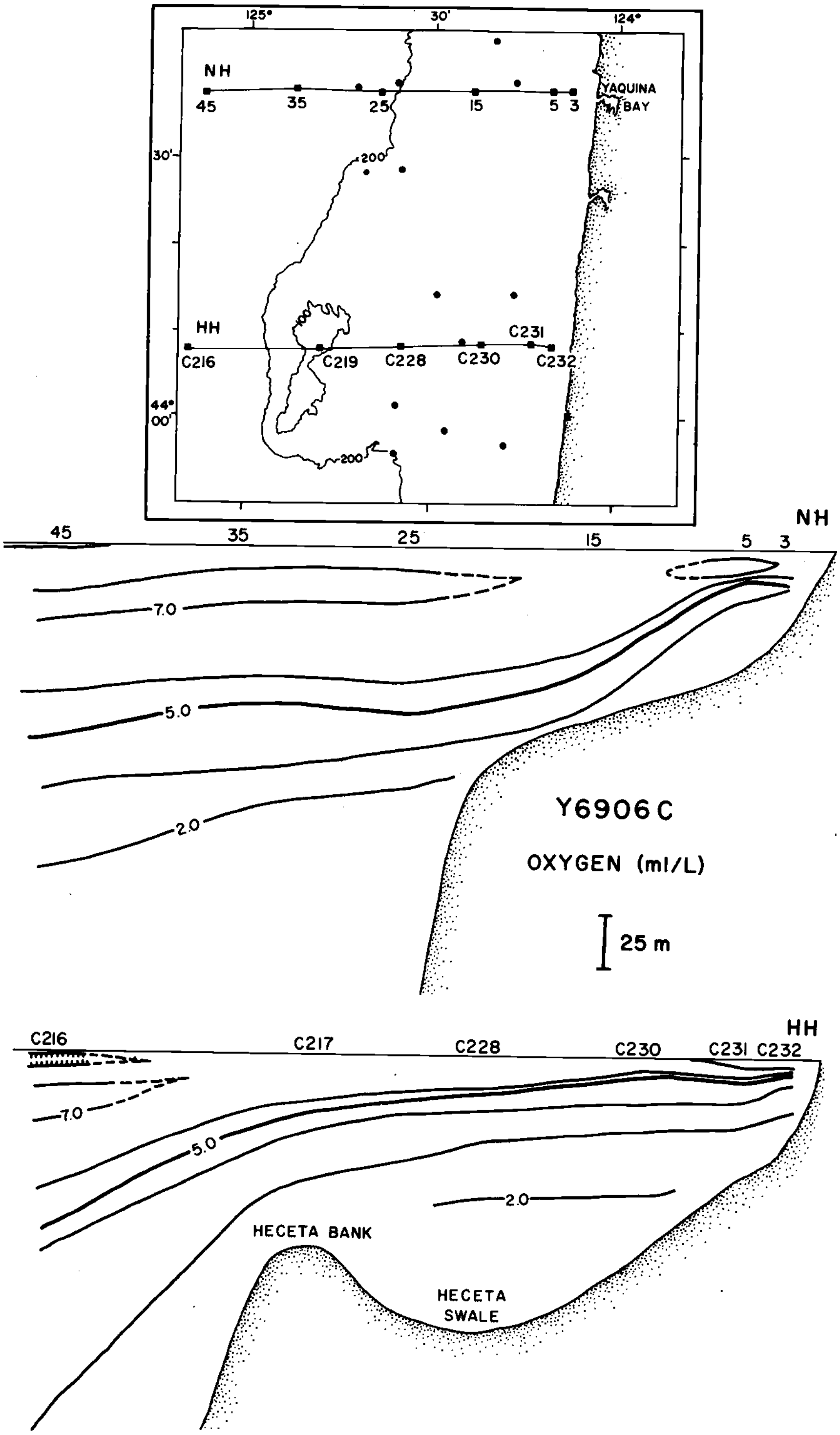

Figure 6. Oxygen concentration along Newport and Heceta Head hydrographic profiles. Data from Wyatt et al. (1970).

The presence of the offshore banks apparently interrupted the normal coastal flow of water; the direction of longshore transport was not parallel to the coast but rather parallel to the bathymetric contours, resulting in a current eddy or gyre behind the banks (Pillsbury, 1971). Upwelling may also have taken place some distance offshore, on the seaward side of the banks. The banks have a pronounced effect on local hydrographic conditions.

Seasonal changes in water characteristics have been shown to affect the animal life of Oregon waters. The seasonal presence of two copepod species is a result of the seasonal shift in surface currents (Cross and Small, 1967). Seasonal variation in Zinc-65 per gram of macroplankton and micronekton, with peak activity in the summer, was observed by Pearcy and Osterberg (1967) and was correlated with the seasonal changes in the location of the Columbia River plume.

Previous Work

Pacific Coast Foraminifera

Since the pioneering work in the ecology of Northeastern Pacific Foraminifera by Natland (1933) off the coast of southern California, many authors have studied the relationships of foraminiferal faunas and species to environmental parameters. Water depth and temperature are generally considered to be the most important factors

(Natland, 1933; Bandy, 1953; Crouch, 1954; Walton, 1955; Reiter, 1959). Sediment type (Walton, 1955; Lankford, 1962; Anderson, 1963; Cockbain, 1963; Resig, 1963; Cooper, 1964), dissolved oxygen concentration (Bandy, 1963a) and nutrient concentration (Bandy, Ingel and Resig, 1964a, b, 1965a, b) have also been considered important. A few authors (Bandy, 1953, 1961, 1963b; Uchio, 1960) have considered other factors important in foraminiferal distribution.

Statistical Foraminiferal Ecology

Statistical approaches have been used in few foraminiferal ecologic studies. Said (1950) calculated the multiple and partial correlation coefficients for total foraminiferal fauna, sediment nitrogen content and sediment median grain size. Kaesler (1966) used presence-absence data from previous studies of Todos Santos Bay to determine biotopes and biofacies by the clustering of similarity coefficients. In like manner Howarth and Murray (1969) employed cluster and factor analysis to evaluate the foraminiferal faunas of Christchurch Harbor. Boettcher (1967) used analysis of variance to compare in-station with between-station variation of selected species. Manske (1968) calculated a coefficient of faunal affinity for all possible station pairs to study seasonal changes in the foraminiferal fauna of Yaquina Bay. Hooper (1969) performed a vector analysis of depth assemblages from the eastern Mediterranean. The diversity and equitability of benthic foraminiferal assemblages have been studied by Beerbower and Jordan (1969) and also by Buzas and Gibson (1969). Buzas (1969) used multivariate regression analysis for autecologic investigation of three species at three stations.

Seasonal Foraminiferal Ecology

Both classic and recently published studies have made it obvious that the abundance of some foraminiferal species is subject to seasonal variations. Meyers (1942) reported a five-fold increase in living *Elphidium crispum* from February 16 to June 15 of the same year at a sublittoral station. High faunal standing stocks during spring and summer are known from southern California (Walton, 1955; Reiter, 1959) and New England (Parker and Athearn, 1959). Hunger (1966) reported high standing stocks at seasonal stations during the spring and fall; he considered the higher number of specimens to be due to increased food supply. High standing stocks of *Elphidium excavatum* in May and October (Haman, 1969) and of *Ammonia beccarii* in May (Brooks, 1967) have been reported. However, Brooks (1967, p. 673) did not find the seasonal difference to be statistically significant.

METHODS

Sample Collection

The author intended to visit each Sea Grant station several times during a two-year cycle of the four seasons. A few additional samples of opportunity were taken on cruises for other projects, and weather and equipment failure prevented the collection of some planned samples. At each station, measurements were taken from the sediment and from the water a short distance off the bottom to provide information about ecologic conditions. On the first cruise at which a station was sampled, three substations (Figure 7) were occupied to give an indication of the substrate and faunal variations within the area to determine if navigational accuracy would allow seasonal resampling (Bertrand, 1971, p. 7, 16).

General Micropaleontology

The collecting, laboratory processing and examination techniques are those in general use, and have been detailed elsewhere (Phleger, 1960, p. 21-24, 30-34; Boettcher, 1967, p. 5). The use of the multiple corer (Fowler and Kulm, 1966) allowed the simultaneous collection of up to five adjacent samples; extremely sandy samples were collected by inserting five core liners into the surface of the sediment sample collected by the modified Smith-McIntyre grab (Carey

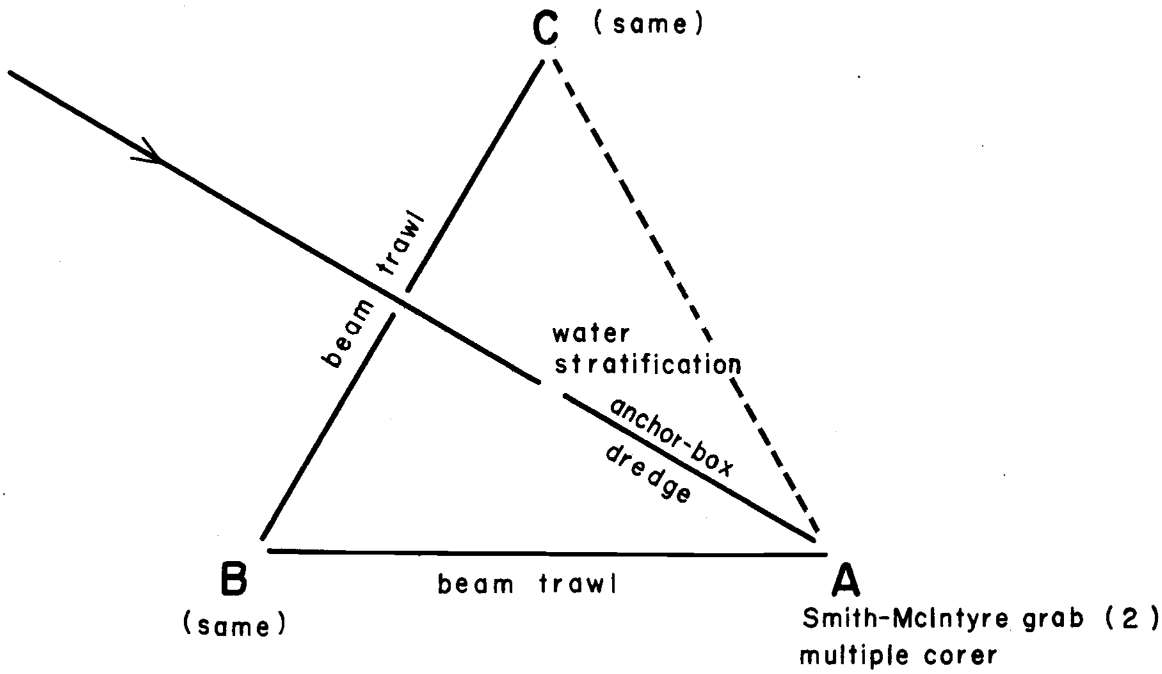

Figure 7. Substation sampling plan for the first occupation of a seasonal station. Distance A-B is one nautical mile.

and Paul, 1968) that was used to collect water samples and biologic samples. At each station, core samples were usually preserved as: three foraminiferal samples, one sediment organic sample and one sediment textural sample. The upper two centimeters from each foraminiferal core were washed on a 63 μ sieve, dried and concentrated before counting the living population. In most cases, the stained specimens (Walton, 1952) from the entire sample were counted; in a very few cases, splits of 1/2 of the collected sample were examined. Unstained specimens were not counted.

Surface Sediment Texture Analysis

Cores collected for surface sediment grain-size distribution analysis at each station on each cruise were analyzed by the Department of Oceanography Sediment Lab using pipette and settling tube methods (Spigai, 1971, p. 36); computations were performed by computer program TEX on the CDC 3300.

Water Chemical Analyses

Temperature and selected chemical properties of the near-bottom waters at each station were collected by the modified Smith-McIntyre grab (Carey and Paul, 1968). Temperature and oxygen were determined onboard ship. Salinity and nutrients were measured by the Department of Oceanography Chemistry Lab from stored samples.

Analytical errors as much as 5% for phosphate measurements and 25% for nitrate and silicate measurements were encountered during the time the Sea Grant samples were measured (Bertrand, 1971, p. 17, 29).

Surface Sediment Nutrient Analysis

Cores collected and frozen for sediment nutrient analysis were processed by the Department of Oceanography Benthos Lab by combustion methods (Bertrand, 1971, p. 22).

Data Processing

Several computer programs have aided the ecologic analysis of the Sea Grant foraminiferal faunas. The programs provided relief from the tedium of hand or desk calculator determination of percentages, ratios and coefficients for the large amounts of data (Krumbein and Sloss, 1958; Kaesler, 1966, p. 3) generated by the Sea Grant Benthic Environment Project. In addition, some computer programs were used to generate bivariate plots. While considerable effort must often be expended to "de-bug" a new program, the ability to repeat numerous calculations and data manipulations justifies this expense.

The computer program SYNECOLOGY (Figure 8) is the author's "workhorse" program. It calculated specimen numbers in a standard sample size, species percentages of the entire fauna and of various

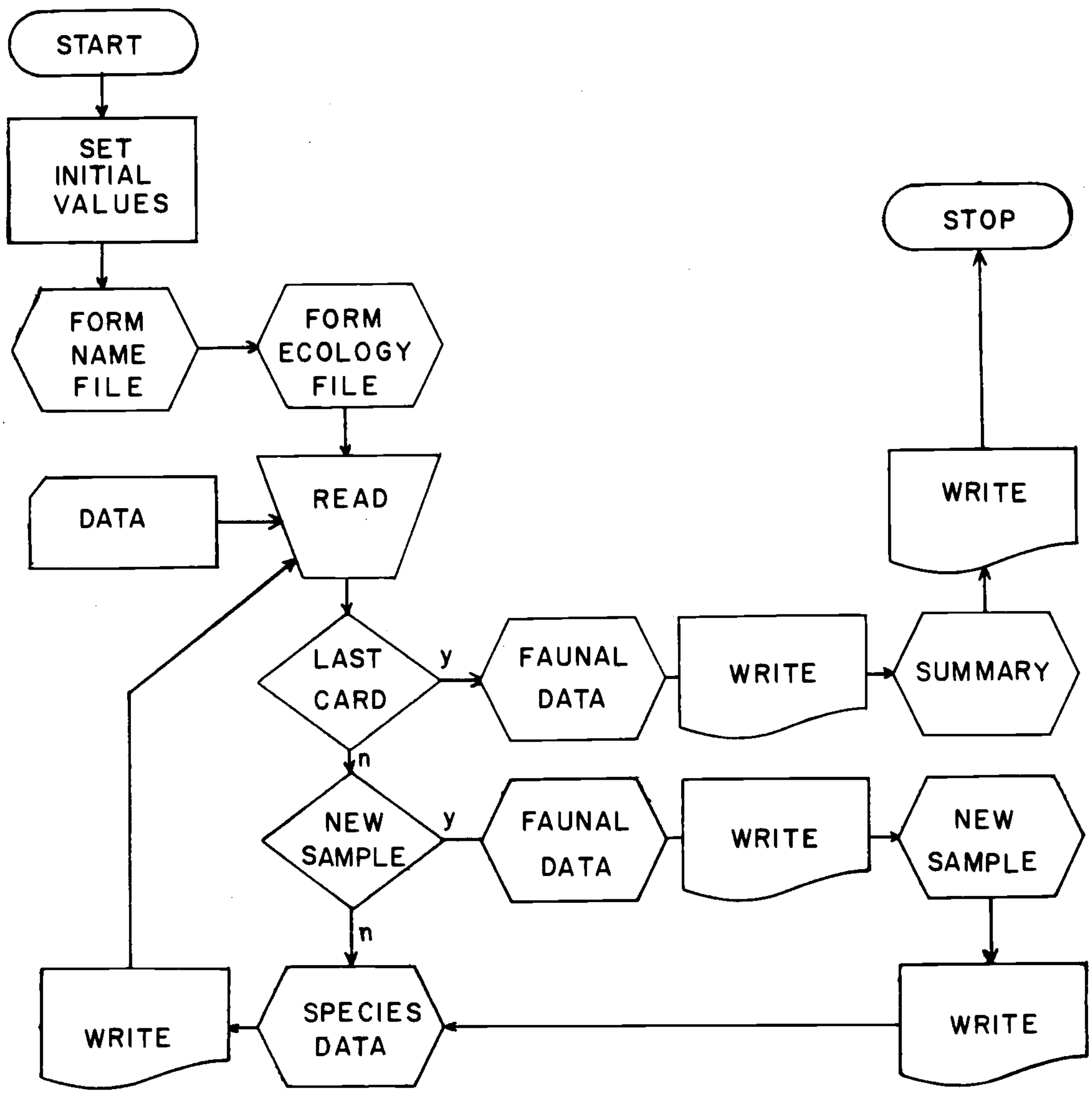

Figure 8. Generalized flow chart of computer program SYNECOLOGY.

faunal subgroups, and faunal parameters for the entire fauna and for faunal subgroups. In addition, it calculated indices of affinity or distance for sample pairs, species-sample arrays and it plotted foraminiferal faunal parameters against ecologic parameters.

Other programs performed specialized jobs in data preparation or manipulation. Computer Center library programs were used for plotting and statistical analysis.

Analysis of Variance

The analysis of variance is a simple and quick way of calculating the variation between groups to determine if the observed variation is greater than can be attributed to chance alone (Miller, 1949). The test uses the variance ratio (F) which has an approximate value of one where there is no statistically significant difference among the group averages, and which increases in value as the group averages differ substantially (Snedecor and Cochran, 1967, p. 265). If the variance between groups is considerably greater than the variation within groups, the groups are not the same.

The analysis of variance is used validly only for data drawn from a normally distributed population. Populations of small whole numbers (counts of specimens) may approximate a Poisson distribution rather than a normal distribution; these may be transformed to a normal distribution by taking the square root of the value (or taking

$\sqrt{X + 1}$ for very small counts). Proportions or percentage data that cover a wide range of values may have a quasibimodal distribution; for these the appropriate normalizing transformation is the arcsin of the value. In some cases a lognormal distribution (where log(X) is normally distributed) is encountered; in this case taking log(X) or log(X + 1) performs the normalizing transformation (Burma, 1949; Snedecor and Cochran, 1967, p. 276-277).

OREGON SHELF BENTHIC ENVIRONMENT

Surface Sediment

Variation Between Stations

The parameters of grain-size distribution from the substation samples taken on the first cruise yielded extremely high values for the "F" statistic (Table 2). All but four values exceeded the 1% level of significance, and of these two exceeded the 5% level of significance. The hypothesis to be tested was that there was a significant difference between the stations. Since so many of the variables tested were significant or highly significant, there is good statistical basis for accepting the hypothesis. A statistical difference in grain-size distribution exists between the several Sea Grant stations.

Variation at the Same Depth

The Sea Grant stations were selected to provide different sediment types at the same depth and to determine if some factor connected with water depth was more important to the benthic faunas than some factor connected with sediment type. The analysis of variance performed on the parameters of grain size distribution when the samples were grouped into classes by water depth showed once again high values of the "F" statistic. Kurtosis, no matter by which method the

Table 2. Values of the "F" statistic calculated by analysis of variance for sediment parameters for cruise C6808E. Significant (*) and highly significant (**) values indicated.

Sediment parameter	Same depth	All stations
Percent sand	3.607**	13.865**
Percent silt	2.921*	12.554**
Percent clay	4.954**	12.276**
<u>Inman Parameters</u>		
Median grain size, ϕ units	3.888**	16.557**
Average grain size, ϕ units	4.537**	12.833**
Sediment sorting	3.126**	4.659**
Skewness	5.561**	8.784**
2-Skewness	1.301	2.146*
Kurtosis	0.590	1.492
<u>Trask Parameters</u>		
Median grain size, mm units	5.387**	7.255**
Sorting	2.307	5.848**
Skewness	3.984**	5.249**
Kurtosis	0.502	2.306
<u>Folk & Ward Parameters</u>		
Average grain size, ϕ units	4.436**	14.349**
Sorting	6.643**	5.642**
Skewness	6.936**	17.094**
Kurtosis	0.855	2.544*
Tr-kurtosis	0.973	5.711**

coefficient is calculated, is the only consistently non-significant size distribution parameter. The hypothesis to be tested is that there is a significant difference. Since most of the grain size parameters are significant or highly significant, the hypothesis can be accepted. A statistical difference exists in sediment grain size between Sea Grant stations at the same water depth.

This difference can be shown graphically as well as statistically. Between 100 and 200 m depth, both the sand content and the median grain size (Figure 9) showed a considerable spread in values.

Seasonal Variation

Comparison of the sediment grain size parameters for all cruises (Appendix III) by analysis of variance (Table 3) showed that, when the cruises are grouped by season and each station is treated separately, at most of the stations the variation in texture is not significant. The significant variations encountered at stations SG-4 and -26 are most likely due to navigational uncertainty and substrate heterogeneity. Both stations are on steep slopes on the outer shelf where a slight shift in position would result in sampling different depths and probably different substrates. The few significant variations at the other stations may reflect seasonal transport of fine material along and across the shelf (Spigai, 1971, p. 128).

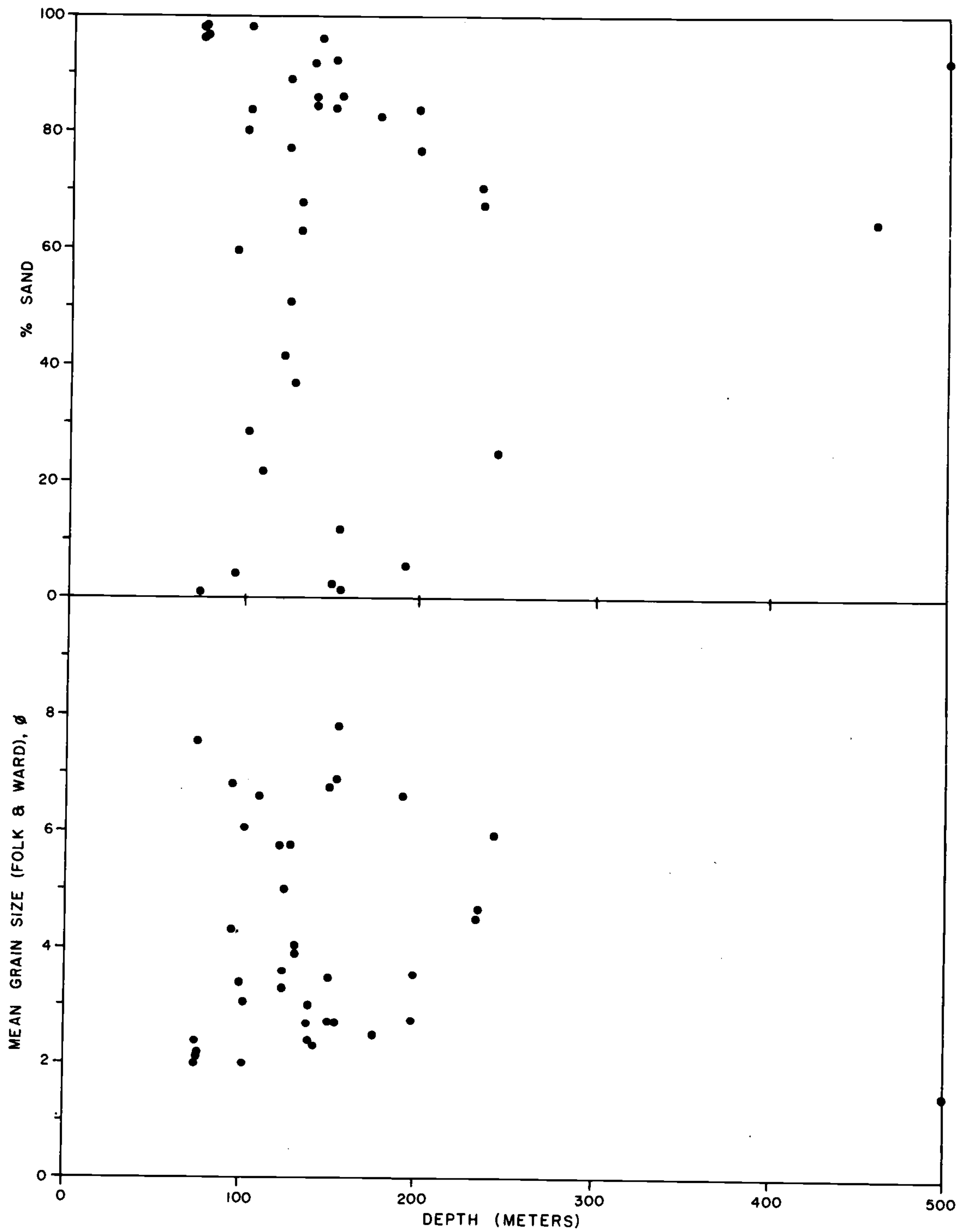

Figure 9. Variation in sediment parameters with water depth.

Table 3. Values of the "F" statistic for seasonal samples from Sea Grant stations. Significant (*) and highly significant (**) values are indicated.

Sediment parameter	Sea Grant Stations										
	2	3	4	6	7	8	10	15	24	25	26
Percent sand	0.415	0.212	114.189**	0.448	1.906	0.555	1.041	1.765	0.441	0.229	8.873
Percent silt	0.546	0.249	95.877*	0.358	0.784	1.264	2.344	1.524	0.200	0.233	4.674
Percent clay	0.453	0.195	19.472*	0.044	5.467*	0.722	0.727	2.841	2.338	0.213	4.111
Inman Parameters											
Median grain size, ϕ	0.857	0.607	2.000	0.587	1.729	0.097	0.263	2.360	0.600	0.244	3.021
Average grain size, ϕ	0.671	0.136	0.999	0.127	2.730	0.432	1.232	1.480	1.134	0.133	8.458
Sorting	0.600	0.054	13.569	0.406	5.543*	0.492	2.447	1.192	1.178	0.237	140.920**
Skewness	0.235	0.782	0.426	0.433	0.809	0.830	2.752	0.344	1.558	0.033	0.474
2-Skewness	0.399	0.079	0.580	4.557	2.227	0.712	3.096	0.272	2.559	0.508	1.000
Kurtosis	0.661	0.165	0.550	0.875	2.427	0.168	6.185	0.248	2.472	0.301	1.271
Trask Parameters											
Median grain size, mm	0.801	0.944	5.573	0.729	1.163	0.140	0.324	2.089	0.671	0.262	5.034
Sorting	0.644	0.521	980.279**	0.179	4.140	0.293	0.577	1.511	1.216	0.091	104.893**
Skewness	0.293	0.415	30.228*	0.749	0.345	0.960	2.607	0.456	1.119	0.043	74.671*
Kurtosis	0.217	1.063	2.866	4.502	0.894	1.384	2.376	0.694	0.935	0.131	34.276*
Folk and Ward Parameters											
Average grain size, ϕ	0.709	0.207	1.109	0.039	2.656	0.312	0.856	1.703	0.991	0.149	5.956
Sorting	0.590	0.051	7.755	0.494	2.760	0.608	1.933	0.849	1.343	0.189	23.926*
Skewness	0.232	1.158	5.212	3.582	0.721	0.861	0.736	1.102	1.339	0.031	1.242
Kurtosis	0.069	0.174	1.786	1.303	1.382	0.156	1.788	0.492	1.159	0.142	1.170
Tr-kurtosis	0.180	0.247	18.654	1.427	1.882	0.148	1.642	1.139	1.746	0.076	1.349

Near-bottom Water

Collections of the near-bottom water have been made on Sea Grant cruises by the Culberson multiple water bottle array (Culberson and Pytkowicz, 1970) and by the water bottle on the modified Smith-McIntyre grab (Carey and Paul, 1968). These samples provide data on the local and seasonal variations in near-bottom water properties.

Within the range above the bottom of 0.6 to 5.0 m the summertime (upwelling) waters are well mixed. Very little variation in hydrographic parameters exists at any one station (Figure 10) but significant differences exist between stations (Table 4). The number of stations is not sufficient to determine if the between-station variation has a geographic base, i.e., if there is a shadow effect of the banks on the near-bottom waters.

During the non-upwelling season (wintertime) the water 0.6 m from the bottom is much more variable than during the upwelling season. Salinity and silicate measurements show a definite gradient with depth; the gradient for phosphate is not as definite (Figures 11-13). In addition, the summertime and wintertime measurements differ significantly.

When the properties of the near-bottom water (0.6 m from the bottom) are examined for each station individually, a general pattern of seasonal variation is observed. At both deep (Figure 14) and shallow (Figure 15) stations, the near-bottom water is relatively low

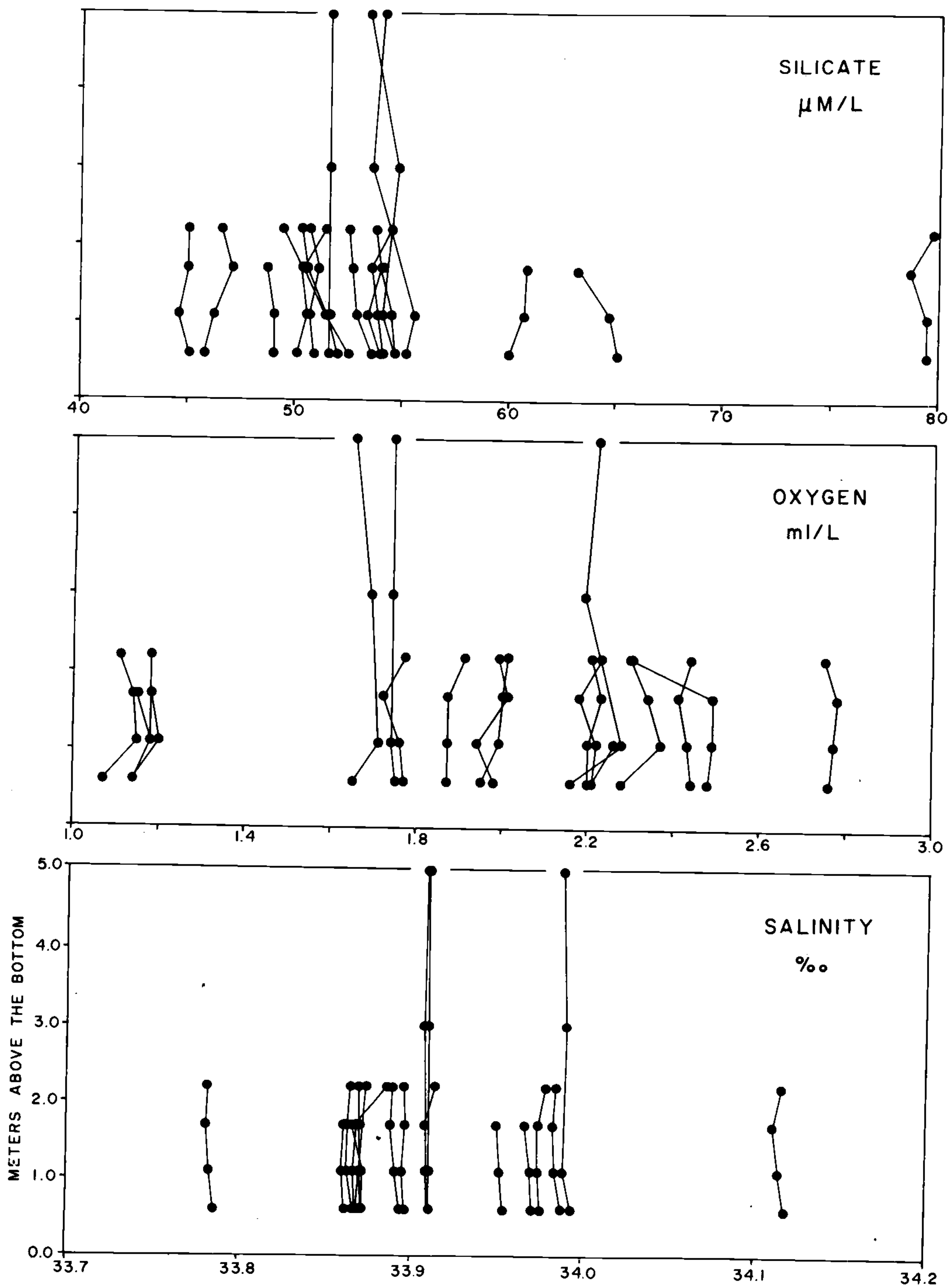

Figure 10. Near-bottom variation in water properties, upwelling conditions (cruise 6808).

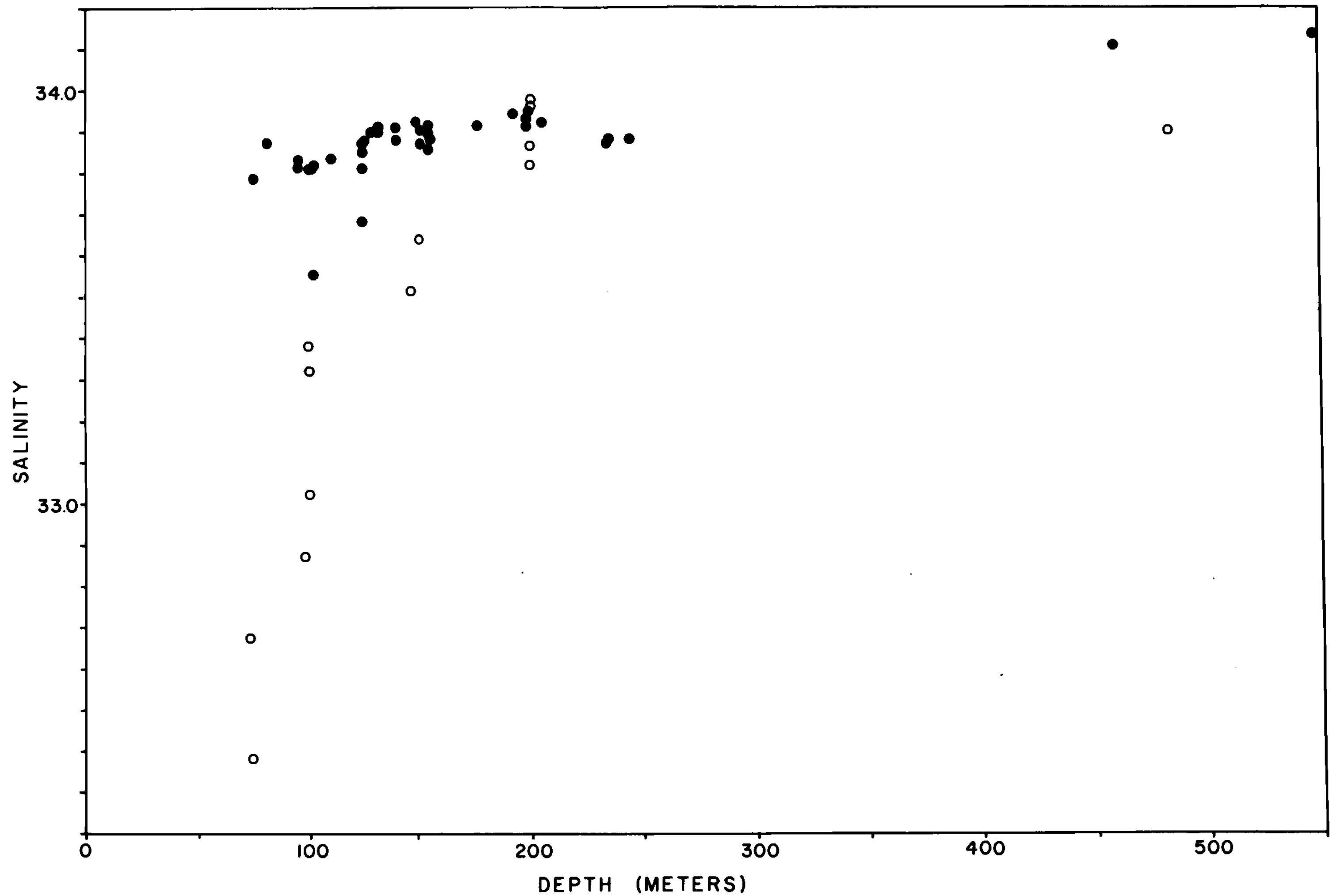

Figure 11. Salinity/depth distribution, upwelling (●) and non-upwelling (o).

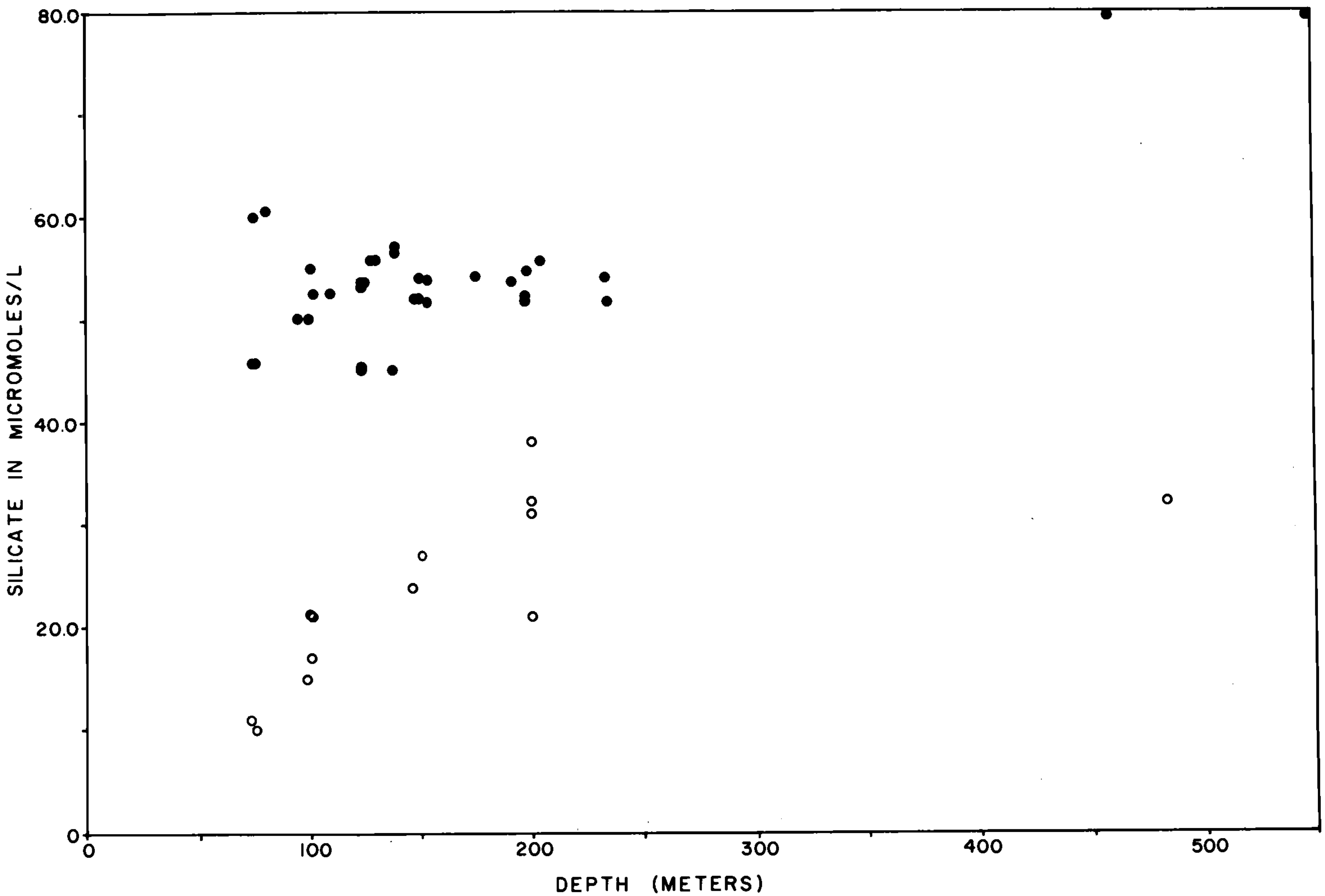

Figure 12. Silicate/depth distribution, upwelling (●) and non-upwelling (o).

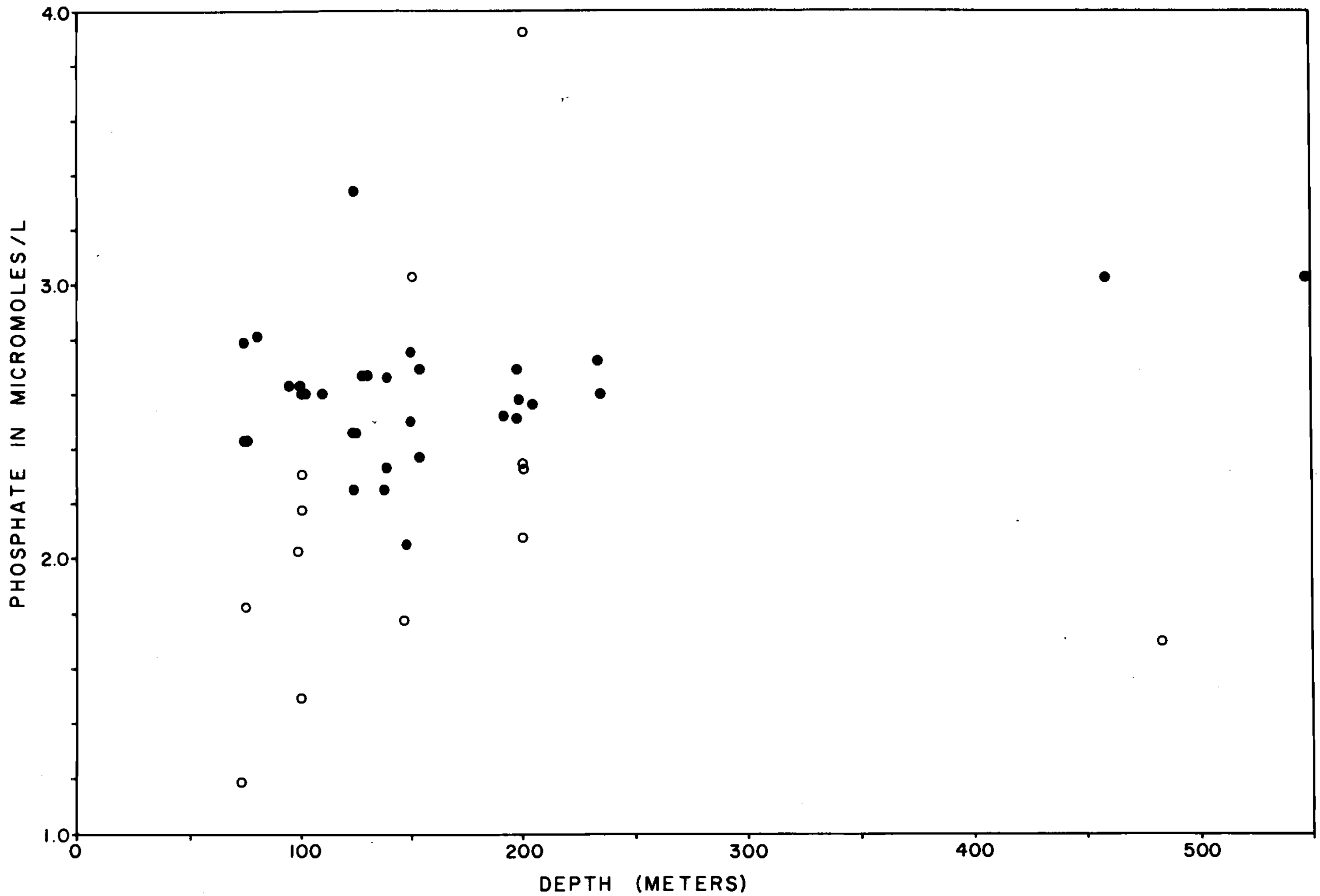

Figure 13. Phosphate/depth distribution, upwelling (●) and non-upwelling (o).

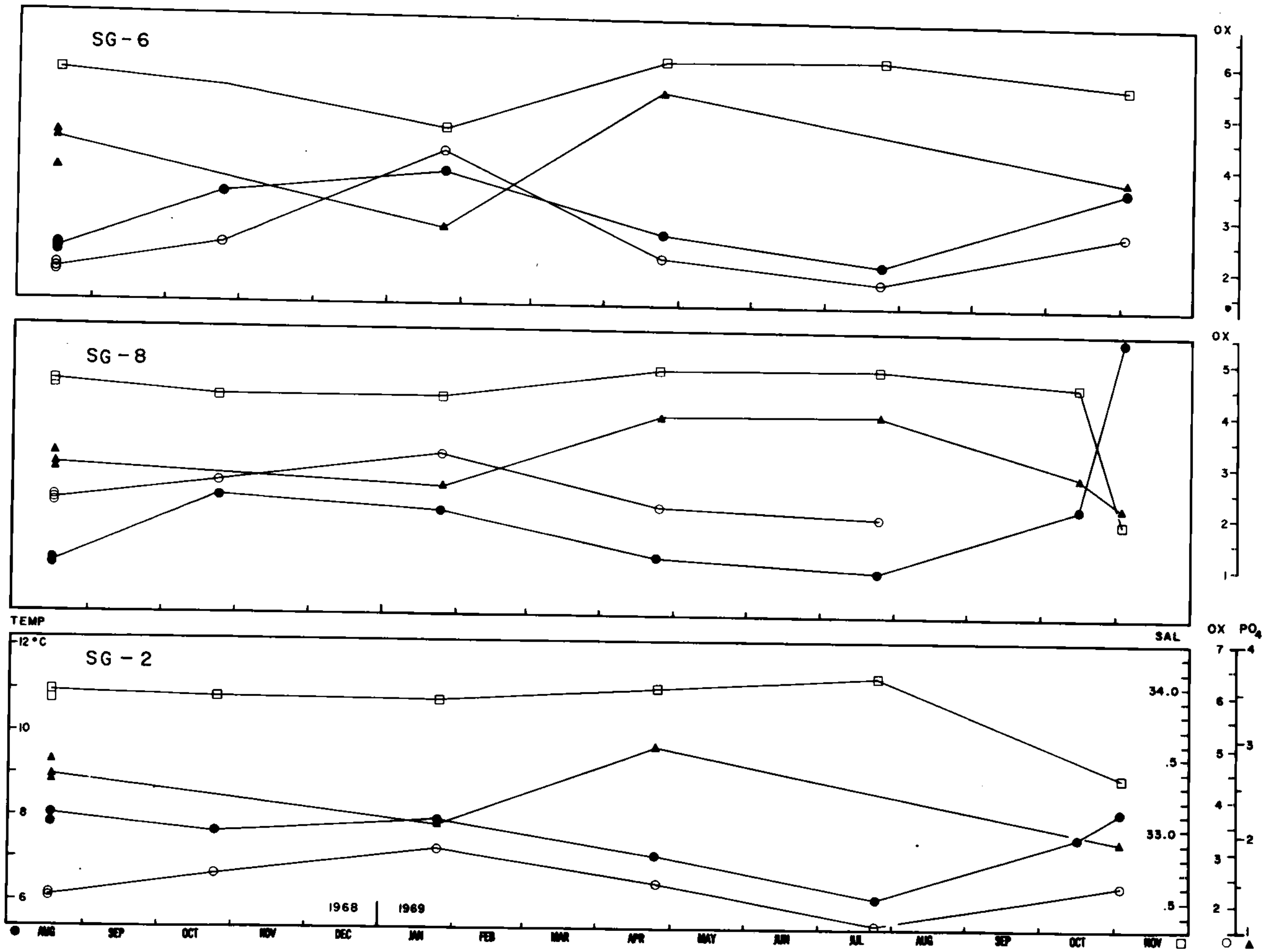

Figure 14. Seasonal variation in near-bottom water properties, deep stations. Symbol identifications are given at the bottom of each scale.

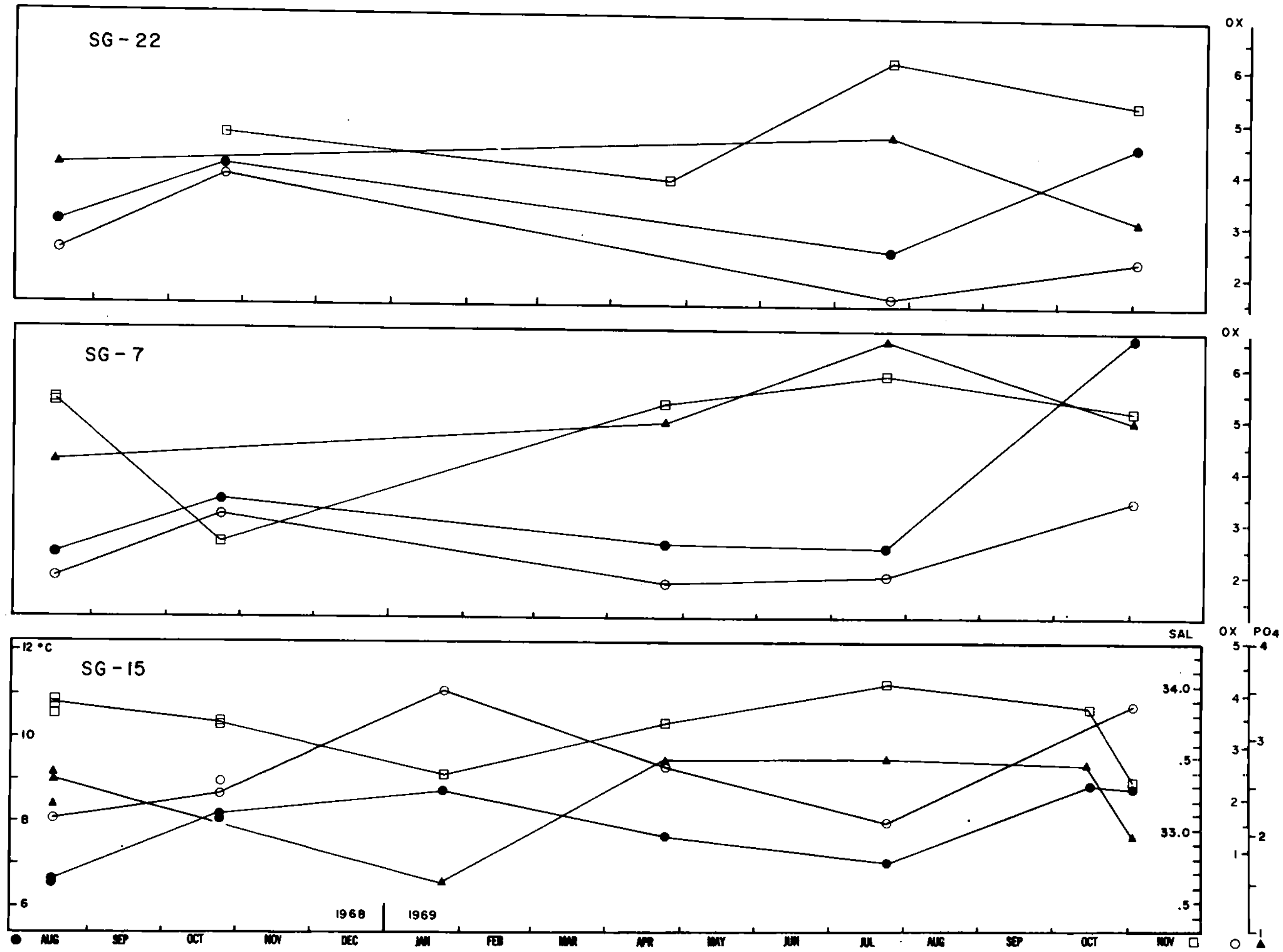

Figure 15. Seasonal variation in near-bottom water properties, shallow stations. Symbol identifications are given at the bottom of each scale.

Table 4. Values of the "F" statistic calculated by analysis of variance for hydrographic parameters collected 0.6 m from the bottom on cruise 6808 (upwelling conditions). Significant (*) and highly significant (**) values are indicated.

Variable	All stations	Same depth
Salinity	2195.628**	165.376**
Water oxygen	1329.101**	6.940*
Water phosphate	32.865**	9.968**
Water silicate	3.513*	8.801*

in salinity and phosphate concentrations and high in oxygen concentration and in temperature, during the non-upwelling season. Conditions are reversed during periods of upwelling.

FORAMINIFERAL ECOLOGY

Synecology

In the synecologic portion of this study, the author is concerned with the ecologic controls operating on the fauna. He suggests that there should be a causal relationship between parameters such as standing stock or diversity and some of the measured environmental factors. The study is based on a total of 80 samples; the eight samples from SG-10 are omitted because of the entirely different fauna found at that depth, and the three samples from the second drop at 6911-2 are omitted to avoid a biased emphasis on that station. The 80 samples include those from the 1969 collections at seven seasonal stations as well as six samples from the 1968 seasonal cruises and six samples from two additional stations on the 6911 cruise. Sample processing accidents, bad weather, and incidents of instrument malfunction did not allow the collection of complete seasonal data at all stations.

Frequency Distribution

Benthic foraminiferal species do not occur in equal abundances, either in each sample (Appendix II), or in data combined from all samples (Table 5). In each sample (Appendix V) a large number of species are represented by single specimens (singletons), a smaller number are represented by two and three individuals, and yet smaller

Table 5. Frequency count of living benthic foraminiferal occurrences for all Sea Grant stations. Frequency count based on specimens actually counted, even in half samples.

No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.
1	942	18	11	35	3	64	1
2	383	19	9	36	7	66	1
3	206	20	8	37	2	78	1
4	159	21	7	38	3	79	1
5	109	22	7	39	1	84	1
6	56	23	9	42	4	91	1
7	71	24	3	44	1	92	1
8	48	25	1	46	2	93	1
9	39	26	4	47	2	95	1
10	28	27	2	48	1	97	1
11	18	28	2	50	2	111	1
12	24	29	6	51	4	135	1
13	30	30	4	54	3	137	1
14	13	31	4	55	4	153	1
15	13	32	2	58	1	191	1
16	14	33	3	60	1	262	1
17	16	34	2	62	1		

numbers of species are represented by larger frequencies.

Similar distributions of frequencies have been noted before in studies with other animal groups. Preston (1948, p. 256) found that the "commonness of species appears to be a simple Gaussian curve on a geometric base (i.e., a "lognormal" curve)." It is possible to determine the closeness of fit to a lognormal curve by determining the sum of the frequencies within class intervals of occurrence (Preston, 1948; Williams, 1953).

When such an analysis is carried out on the present data, a general inequality of frequencies for the class intervals is observed. This indicates a general deviation from a lognormal distribution. In most cases, the rare species are much more frequently represented than expected. Similar departures from randomness have been attributed to an intense search for rarities and to systematic underestimation of flocks of very common species of birds (Preston, 1958). The examination and counting methods used in this study preclude the existence of such errors. The observed dominance of some species must reflect fundamental aspects of the biology or ecology of the community involved (McNaughton and Wolf, 1970, p. 136).

Faunal Affinity

Various coefficients or indices have been widely used in attempts to group samples on the basis of their contained faunas. In this study, the two coefficients used are calculated from percent abundance data rather than from presence-absence data.

Simpson (1949) has proposed the use of a general distance measure to describe the relationship between two communities. Each member of a pair of communities has a different proportion of species, so that as the proportions increase in difference, the distance between the two communities increases. Samples with identical percent abundances have a separating distance of zero; samples with no species in common have a distance of 100.

Another index of affinity has been used by Wieser (1960) to compare benthic faunas in Buzzard's Bay, by Manske (1968) to compare benthic foraminiferal faunas in Yaquina Bay, by Day and Pearcy (1968) to compare benthic fish faunas off Newport and Waldport, and by Miller (1970) to compare samples of marine zooplankton. The value of the coefficient is obtained by summing the minimum percent abundance for each species common to the pair of samples. Since minimum values are added, the coefficient measures the minimum affinity, or the percent overlap, between the two samples. If the samples have no species in common, the value of the coefficient is zero; if the samples are identical, the value of the coefficient is 100.

The Sea Grant stations can be grouped on the basis of faunal similarities. When a trellis diagram is constructed for all possible combinations of sample pairs (Table 6), the degree of faunal affinity

Table 6. *Index of faunal affinity for all possible sample pairs and average affinity for all possible station pairs.*

Average affinity for station pairs (Index):

Station	22	15	7	26	25	9	6	2	8	10
22	58.2	13.5	9.2	12.5	11.7	12.4	17.7	7.9	10.5	10.6
15		44.8	39.2	30.2	41.6	43.5	36.5	30.6	34.7	14.3
7			62.2	19.3	54.3	43.8	38.2	26.9	32.4	12.7
26				37.6	32.9	31.9	27.4	37.4	34.2	14.1
25					71.7	60.0	55.0	46.4	53.4	13.8
9						67.7	56.3	45.1	52.7	17.6
6							60.3	37.1	54.3	16.1
2								57.8	54.2	14.0
8									62.4	13.8
10										36.5

Sample pairs, station 22:

Station	22C.1	22.2	22.1	22.2	22.3	22.1	22.2	22.3	22.1	22.2	22.3
6808 - 22C.1	-										
6810 - 22.2	71	-									
6901 - 22.1	57	54	-								
- 22.2	77	86	52	-							
- 22.3	52	70	46	65	-						
6907 - 22.1	59	54	49	50	34	-					
- 22.2	57	58	51	62	41	56	-				
- 22.3	64	54	52	53	43	70	50	-			
6911 - 22.1	60	58	49	57	37	64	55	62	-		
- 22.2	63	66	51	63	52	63	49	62	68	-	
- 22.3	64	79	54	71	61	61	50	58	60	76	-

between stations can be shown. Unfortunately, statistical tests cannot be used to determine the significance of sample affinities (Miller, 1970, p. 736) so that evaluation must be done by eye or by cluster analysis. The former was used in this study.

Usually any sample taken at random shows greatest affinity for other samples taken at the same drop. Close affinity is shown for other samples taken at the same station but on different cruises. Close affinity for samples from other stations is found where the percent composition of the samples is similar, and is the basis for saying that the faunas are similar.

The affinities between stations present some surprising results. Strong faunal affinities cross the depth and sediment boundaries that were originally used to select the different stations (Figure 2, 16-18). Only stations SG-22 and -10 have such low affinities as to not be linked with any other station. Stations SG-2, -6, -8, -9, -25 and -26 form a cluster with mutually strong affinities. Stations SG-7 and -15 appear to represent boundary faunas of the main fauna.

The major faunal boundaries appear to be determined by water depth. Stations SG-15, -22 and -26 all have very high sand percentages in the sediment and they cover a relatively narrow depth range. Yet there is a sharp faunal boundary separating SG-22 from the others. This boundary may be the same as the boundary between fauna B and fauna C found by Boettcher (1967) at 100 m, but species

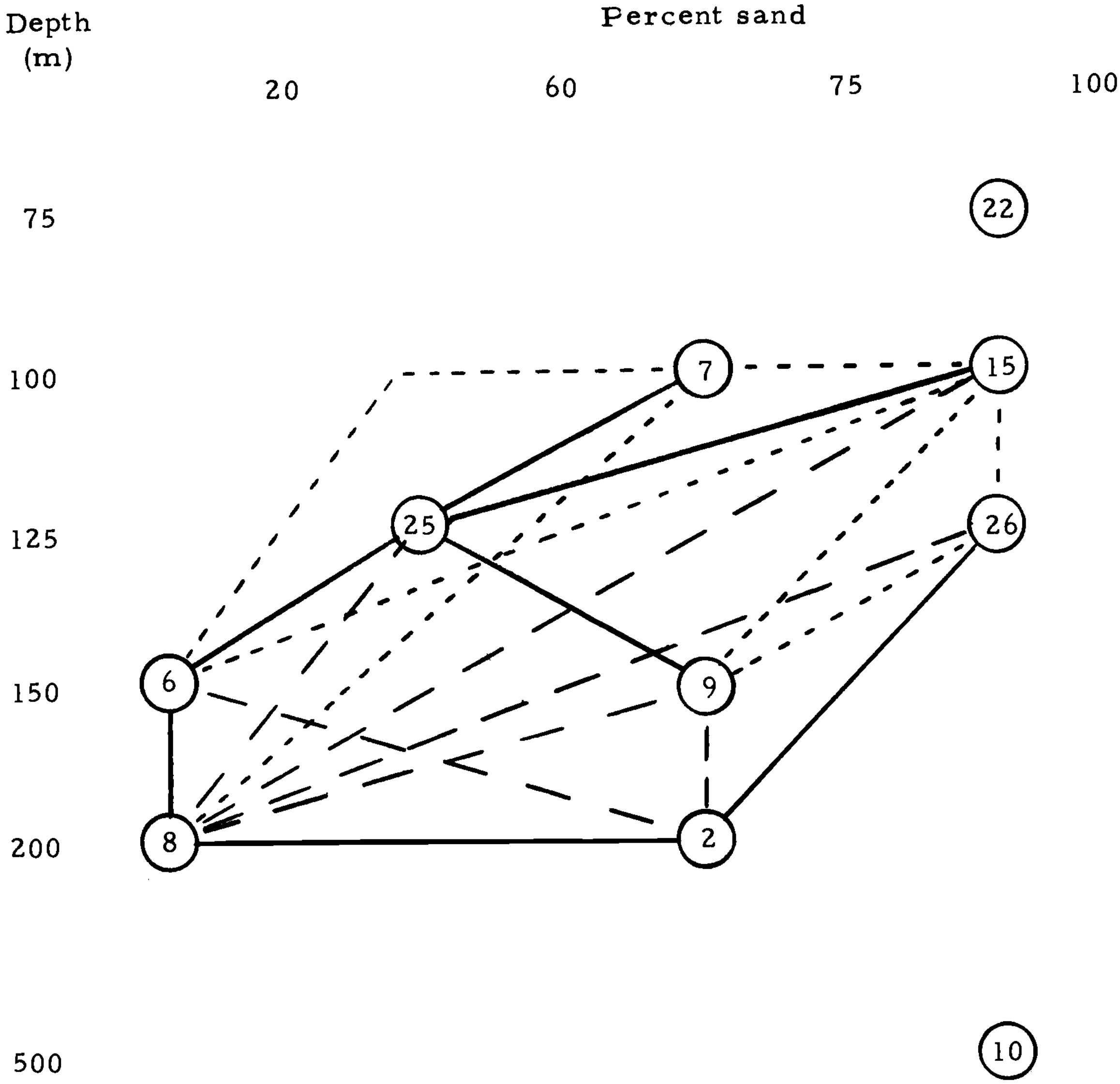

Figure 16. Foraminiferal faunal affinity relationships between stations on a depth-sediment grid. Average affinity used (see Figure 17).

groups on each side of the boundary are not the same in this study and in Boettcher's.

The cluster of stations is not a geographic unit (Figures 17 and 18). The stations with the highest affinities are usually geographically proximate to each other, but high affinities are found between stations at some distance from each other and separated by the banks. It would appear that the bank effect on local hydrographic conditions is less important to the benthic foraminiferal fauna than water depth or sediment type.

Within-station Variation

Further examination of the species abundance data (Appendix II) will show the existence of considerable variation in the relative abundances of the dominant species between cores taken by the same drop of the multiple corer. For example, *Cribrostomoides columbiensis* has abundances of 13, 5 and 3% in the three cores from station 6907-2 and of 12, 5 and 7% from 6904-15. *Brizalina pacifica* has abundances of 22, 31 and 50% from 6904-2, of 43, 36 and 23% from 6911-2, of 32, 5 and 20% from 6901-8 (Figure 19), and of 44, 28 and 30% from 6904-26. *Eggerella advena* has abundances of 37, 22 and 47% from 6907-22. *Saccammina difflugiformis arenulata* has abundances of 73, 27 and 50% from 6901-22 (Figure 20). Many more examples could be cited (Figures 21 and 22).

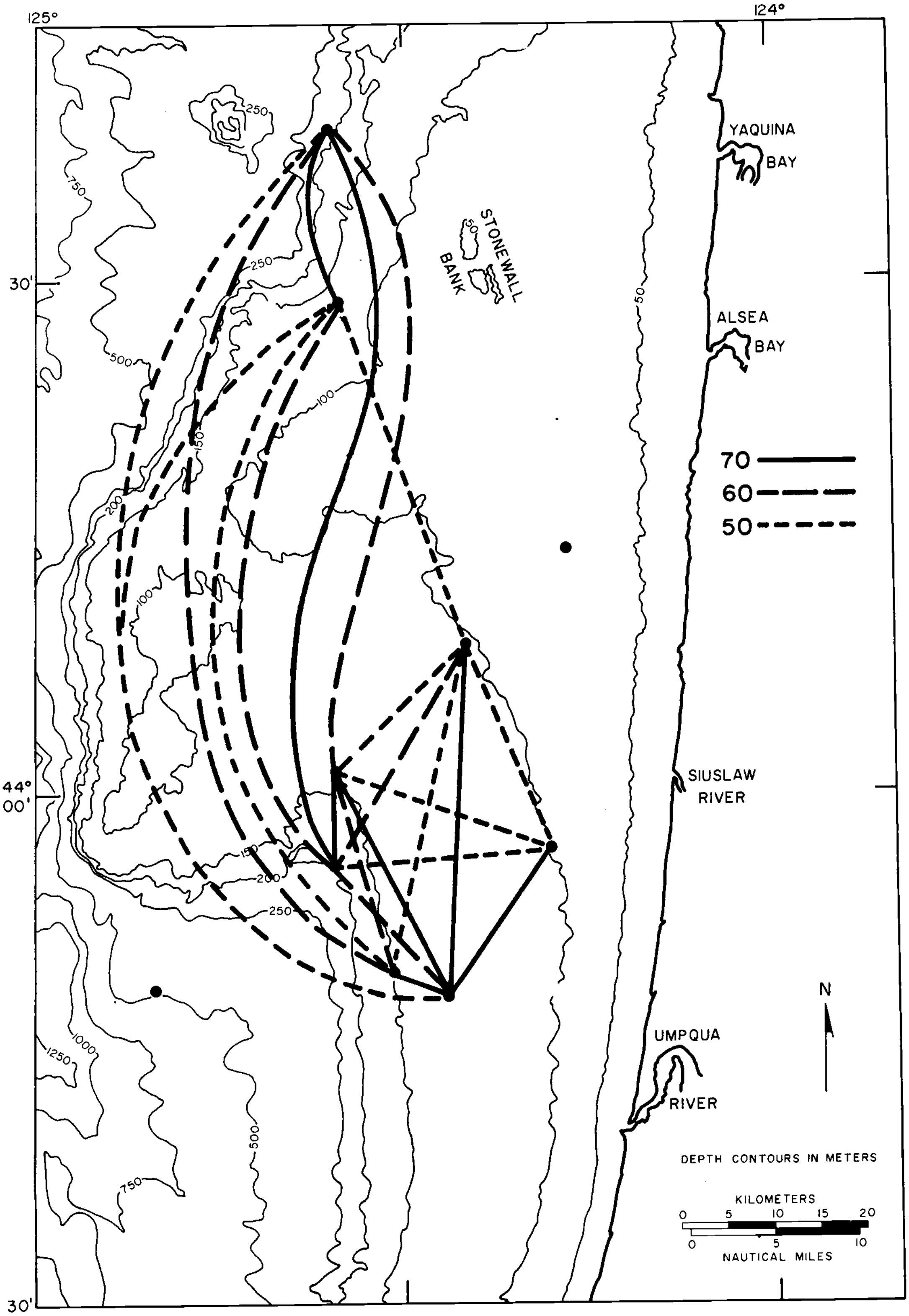

Figure 17. Station faunal affinities, average affinity for each station pair.

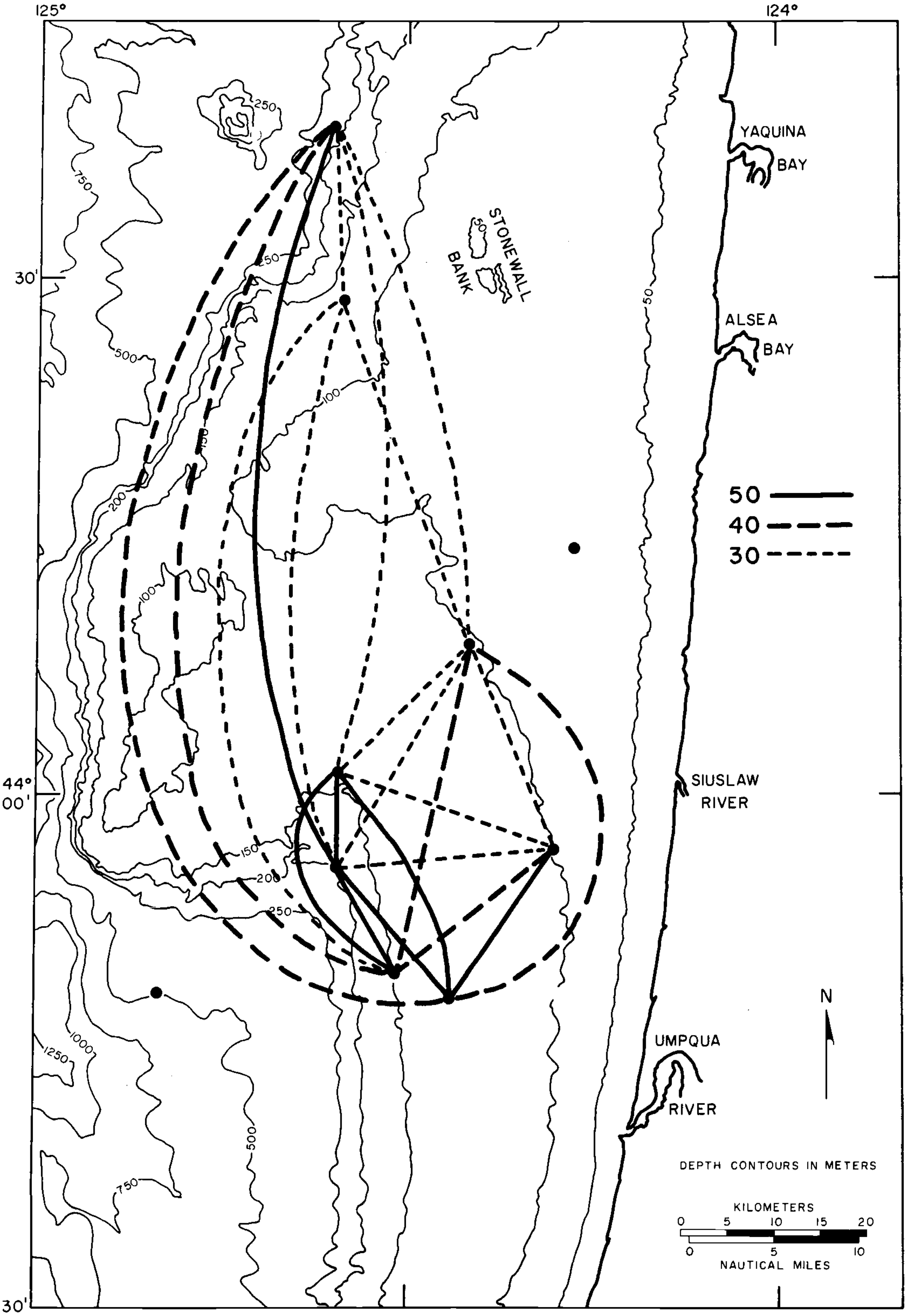

Figure 18. Station faunal affinities, maximum affinity for each station pair.

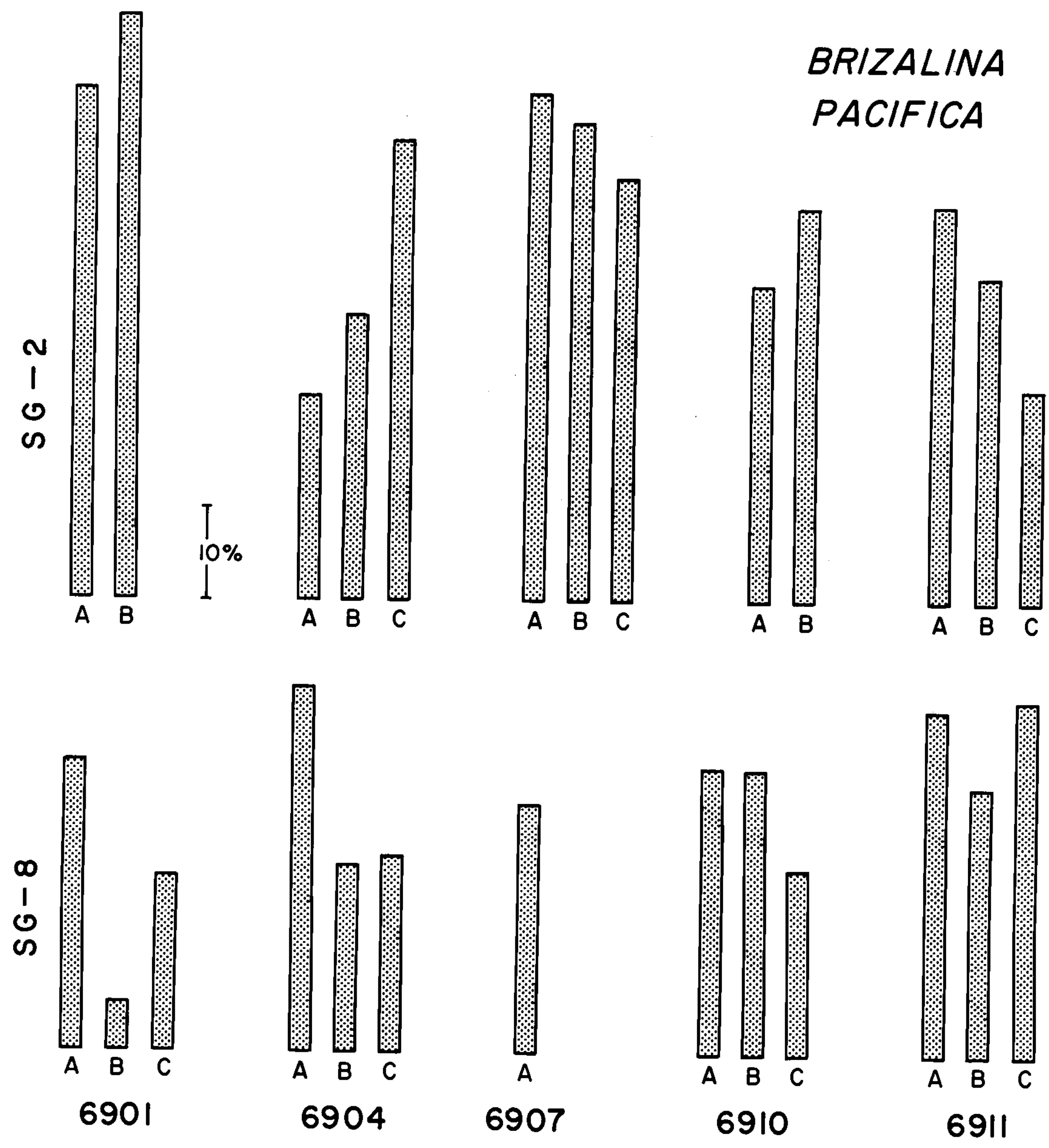

Figure 19. Variation in percent abundance of Brizalina pacifica in seasonal collections at two Sea Grant stations.

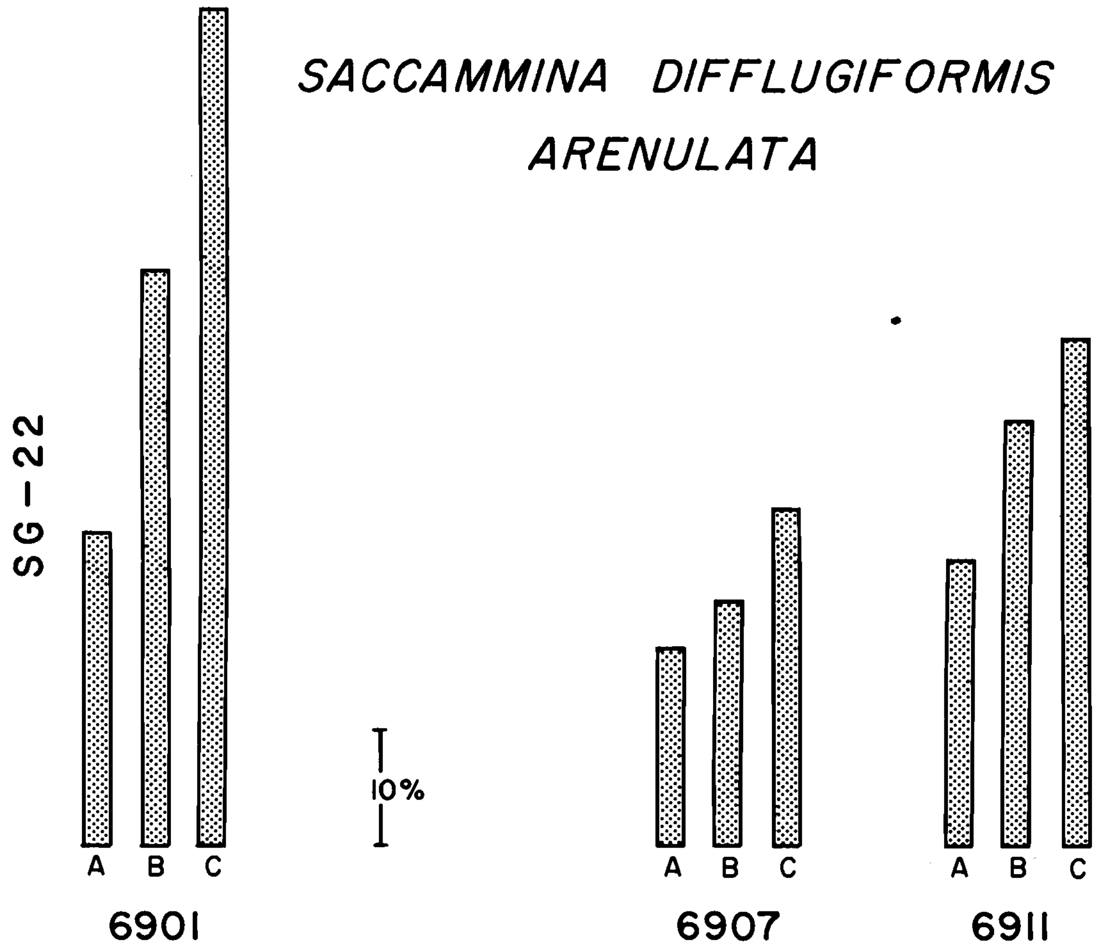

Figure 20. Variation in percent abundance of Saccammina difflugiformis arenulata in seasonal collections at Sea Grant station 22.

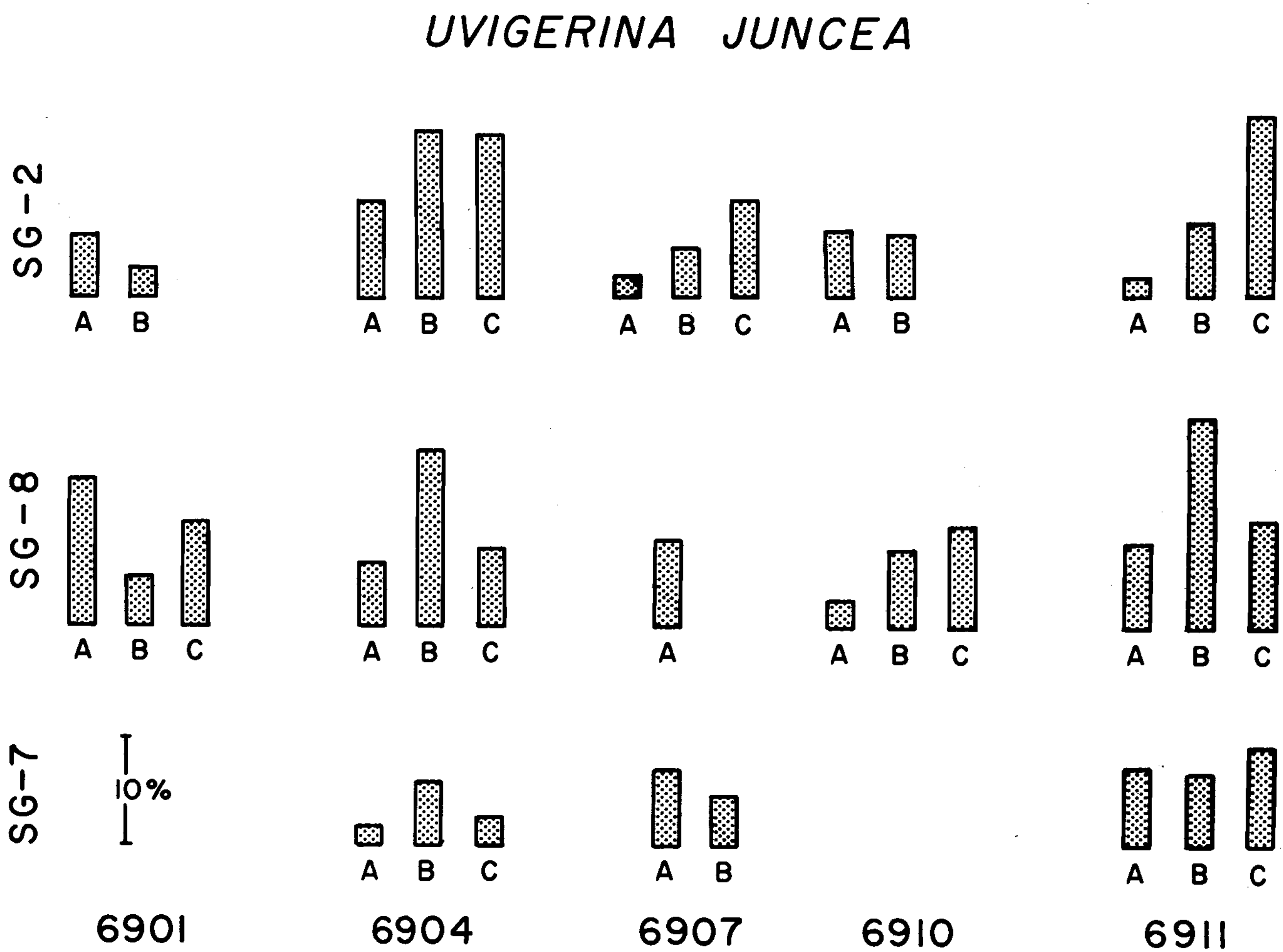

Figure 21. Variation in percent abundance of Uvigerina juncea in seasonal collections at three Sea Grant stations.

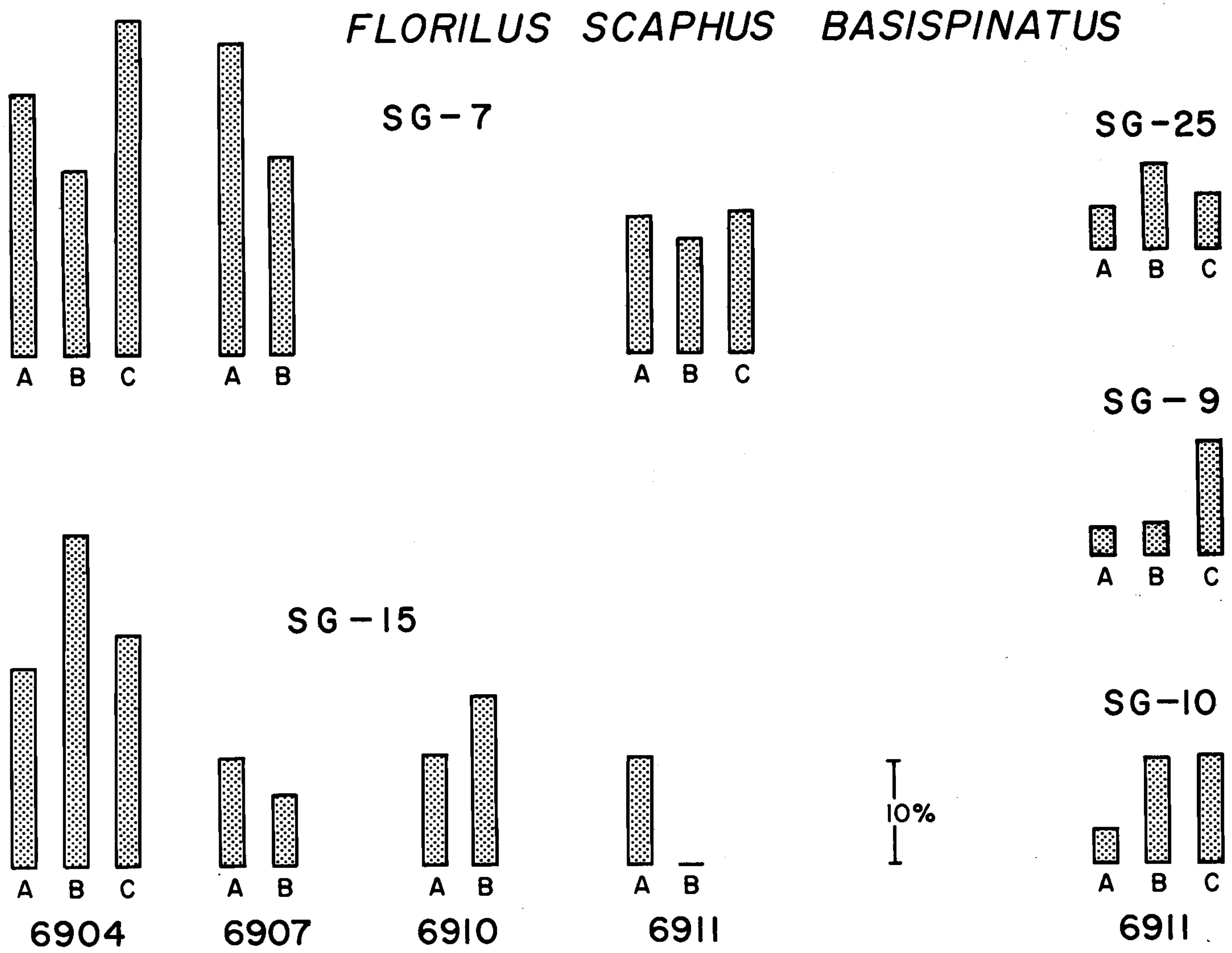

Figure 22. Variation in percent abundance of Florilus scaphus basispinatus in collections at several Sea Grant stations.

The variation in percent abundance of the dominant foraminiferal species has led to a re-examination of the assumptions concerning the microdistribution of benthic foraminifers.

In most distributional studies, no matter what the organism or area studied, the samples correspond to point samples. In other words, the sample is taken from a very small area but is considered to be representative of an area very much larger, as determined by the spacing of stations. In cases where replicate samples at one station are taken, as in this study, it is assumed that the variation between subsamples is much less than the variation between stations, but is not negligible. It is this assumption that is now to be examined.

Foraminiferal microdistribution was investigated previously by Shiffett (1961) who concluded from SCUBA-collected samples at depths of 12-18 m (40-60 feet) that there was appreciable variation in living foraminiferal percentages and standing crop; she concluded that benthic foraminifers were not uniformly distributed but lived in colonies. Lynts (1966), working at depths of 0.9-2.7 m, considered that foraminiferal colonies covered at least 30 m^2 at most of his stations and that dominant species were fairly constant. Boettcher (1967, p. 81), using samples collected with the multiple corer, found some instances of considerable variation in percent abundance of a given species; he found that in-station variation did not exceed between-station variation along any one traverse. Buzas (1968) intensively sampled a small area at a depth of 1 m, and found that the dominant species were clumped while non-dominant species were random in occurrence. Boltovskoy and Lena (1969b) in grid samples of six small areas observed extreme irregularities in total standing stock, in number of species, and in percent abundance of dominant species (Buliminella elegantissima and Elphidium macellum) and concluded that foraminiferal colonies were irregularly spread over a few square meters in area, with sharp boundaries over distances of 10-20 cm.

On the 6911 Sea Grant cruise, it was possible to make two multiple corer drops at some stations, yielding a grand total of six cores for foraminiferal analysis. All six cores from station SG-2 were examined to determine if the faunas of the samples collected by the two drops were different (Figure 23). If the two faunas of the drops are very similar, then the unknown distance between drops (due to navigational uncertainties and ship's drift) was still within the same environment. If the fauna of each drop is internally similar but the drops do not compare with each other, then the 200 m environment is heterogeneous on a scale of several hundred meters, at best. If the foraminiferal assemblages of each core within a drop are not similar, then the environment is heterogeneous on a scale of a few centimeters.

Comparison of the six foraminiferal collections was made in several ways. Simpson's distance function (Table 7) showed only a

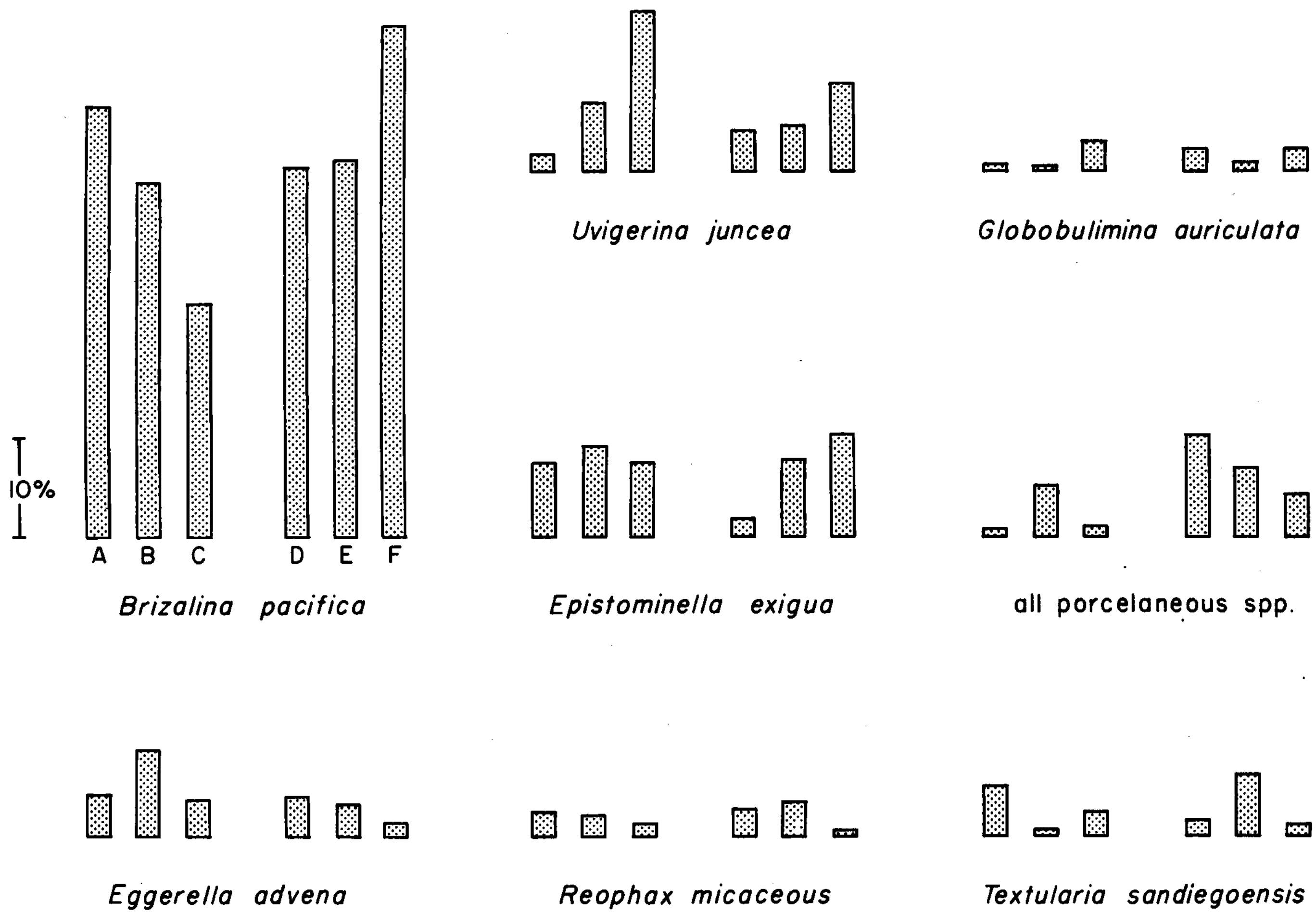

Figure 23. Percent abundance variation for several species in samples from two MC drops at station 6911-2.

Table 7. Simpson's Distance Function for the living benthic foraminifera present in six cores taken on two different drops at station 6911-2. Both individual core and average values are given.

	Samples					
	Drop 1			Drop 2		
	2.1	2.2	2.3	2.4	2.5	2.6
2.1	-		28.13			
2.2	23.6	-				27.05
2.3	32.8	28.0	-			
2.4	26.3	24.3	36.2	-		
2.5	20.1	16.2	31.0	23.0	-	27.49
2.6	21.4	27.5	40.5	32.2	26.4	-

small distance between cores, with nearly identical average values for within- and between-drop comparisons. The index of faunal affinity (Wieser, 1960) also showed close correspondence between faunas, both within and between drops (Table 8). Analysis of variance of the diversity parameters showed no significant variation within or between drops. The author concludes that the observed variation between drops is minor, and that there is a consistent fauna at the station. The close agreement means that any two cores from different drops at the same station are no more different than any two cores from the same drop.

Microdistribution

The next consideration is the source of the within-station variations. What statistical, physical or biological explanation best fits the observed variations and our knowledge of the benthic environment and of foraminiferal biology?

In a classical paper, Chamberlin (1897) admonished the investigator of geologic phenomena to keep in mind multiple working hypotheses, and to seek supporting and refuting data for each of the several hypotheses. This admonition was intended to assist the investigator in avoiding the inappropriate defense of a favorite "ruling hypothesis." Following this advice, the author considers that the observed variation in species relative abundance in adjacent cores

Table 8. Indices of Faunal Affinity (Wieser, 1960) for the living benthic foraminifera present in six cores taken on two different drops at station 6911-2. Both individual core and average values are given.

	Samples					
	Drop 1			Drop 2		
	2.1	2.2	2.3	2.4	2.5	2.6
2.1	-	62.60			64.45	
2.2	67.33	-				
2.3	58.86	61.62	-			
2.4	64.67	67.18	56.04	-	64.35	
2.5	72.42	71.83	60.44	68.25	-	
2.6	67.90	67.65	52.45	60.45	64.34	-

can be attributed to at least one of three or more different sources: 1) sampling error in determining the counted number of specimens and hence the relative abundances of the species; 2) physical or chemical microheterogeneity in the substrate; and 3) biologic interactions.

Sampling Error. Sampling error may be considered to be the difference between the characteristics of a sample and the characteristics of the population that the sample is intended to represent (Burma, 1948, p. 727; Garrett and Woodworth, 1958, p. 184-209). In the collection and processing of foraminiferal samples, sampling error may be contributed to by at least the following: 1) heterogeneity of the environment (Krumbein, 1934) or non-random microdistribution of the animals; 2) variations in sample size as the core is extruded and the top 2 cm sampled; 3) differential fixing and preservation by the buffered formalin; 4) differential staining; 5) differential loss or destruction of specimens during laboratory preparation (washing, drying, concentration and curation); 6) splitting and counting errors, especially where stained specimens may be hidden by large mineral grains or tangled up in algal material; and 7) reliability of the stain as an indicator of foraminifera that were living at the time of collection (Walton, 1952, p. 60). Phleger (1960, p. 33) speculated on the basis of his experience that a 10% error existed in the actual counting and identification of specimens from a sample.

Unless a study is designed to evaluate the components of sampling error, sampling error can be measured only as the gross variation between samples. Standard deviation, standard error, standard error of the mean and probable error are commonly used measures of variation among samples (Garrett and Woodworth, 1958).

Probable error has been used to indicate the accuracy in percentage representation of species frequencies (Phleger, 1960, p. 33). and as an indicator of the accuracy of heavy mineral frequency data (Dryden, 1931). However, Dryden (p. 237) did not wish ". . .to introduce. . .new or fancy methods for representing the results of heavy mineral analyses." He merely intended to make the investigator aware of the errors inherent in the analysis so that an apparent accuracy greater than genuine should not be assumed or indicated.

In the present case, it is not possible to separate the field errors from the laboratory errors (Krumbein, 1934). The author agrees with Peterson (1971) that in most sampling programs the greatest variation between subsamples is due to variations in the field rather than to laboratory errors. But it is not possible at this time to rule out sampling error as a complete explanation for the observed within-station variation.

<u>Substrate Microheterogeneity.</u> The physical or chemical components of the microhabitat may not be uniform on a scale appropriate to the size of a foraminiferan. Ripple marks are known

to exist on the ocean floor at much greater depths than presently studied. Many larger benthic animals, both infauna and epifauna, have feeding habits that produce physical and/or chemical heterogeneities in the surface sediments (Sverdrup et al., 1942, p. 894). Examination of deep-sea camera records for areas close to SG-2, -6 and -8 (camera stations 6705-104, -105, 6709-119-2, -119-3) showed that ripple marks might be present at SG-2 and -6, but that they were formed only occasionally; the observed ripple marks were poorly preserved, with evidence of reworking by benthic organisms and blanketing by the deposition of fresh sediment (Neudeck, 1968). In addition, experimentation with terrestrial seeds (Harper, Williams and Sagar, 1965) has indicated the importance of microtopography in the establishment of seedlings; extreme local success yielded a clumped distribution. Similar microheterogeneities in the surface sediment might result in the observed variations in abundance.

Biologic Heterogeneity. If we assume that the physical and chemical components of the microhabitat are uniform within the area sampled by each drop of the multiple corer, then the observed variations may be due to biologic factors. Such biologic factors as competition, mutualism, predation and commensalism (Odum and Odum, 1959, p. 226) have not been identified in foraminiferal faunas, but may be presumed to be operating. An instance of foraminiferal parasitism on another foraminifer has been reported (LeCalvez, 1950,

p. 239). At present, it seems most likely that some undetermined biologic activity is responsible for the observed variations in percent abundance of foraminiferal faunas.

For extremely shallow-water foraminiferal faunas, a model has been proposed that offers an explanation for the present observations. Buzas (1968) considered that the foraminiferal species with low abundances were randomly distributed while the dominant species in his samples were aggregated. He considered that the aggregations were colonies of siblings produced by asexual reproduction (see also Meyers, 1937, p. 94). Random distribution over the substrate was achieved when sexually produced individuals settled down onto the substrate after gametic union and perhaps early development within the water column (Lidz, 1966). Specimens suspended by turbulence (Meyers, 1943, p. 453; Murray, 1965; Loose, 1970) would also be expected to settle out in a random manner.

The author considers that species-specific differential survival on different substrates, or perhaps species substrate selection, adds an important ecologic dimension to the model. Species for which the environmental conditions were optimum on a particular substrate would grow and thrive; they would be the dominant species. Species for which the environmental conditions on that substrate were not optimum might grow, and might occasionally reproduce, but would not thrive (Hardy, 1965, pt. 1, p. 125). Success on a substrate may depend upon either gross or microproperties of the environment.

The preference of a foraminiferal species for a certain substrate has been noted before. Brady (1888) noted with surprise that a species of Orbitolites was "parasitic," and usually firmly attached to a coralline algae. Meyers (1935) reported that Patellina corrugata was firmly attached to substrates that supported populations of diatoms. Arnold (1954) has emphasized substrate preference for the benefit of those who would like to culture foraminiferal species.

The poor fit of species frequency distributions to the lognormal distribution may be a result of this model. The large number of singletons would be the species that found the environment at that place not sufficiently hospitable to allow reproduction. The small number of dominant species would be those that found the environment at that place extremely hospitable. In different terms, the dominant species are more efficient in the exploitation of niche overlap zones under a given set of environmental conditions (McNaughton and Wolf, 1970).

The low number of adjacent samples (three) in the present study does not permit analysis for closeness of fit to either the binomial (random distribution) or the negative binomial (aggregated distribution) of species abundance data (Buzas, 1968). For this reason the author is unable to do more than suggest that the above model might be one of several explanations for the observed within-station variations.

The author has an intuitive feeling that the above model provides the most accurate and realistic explanation for the observations, but he is unable to provide conclusive proof.

Environmental Effects

The physical-chemical environment of the ocean floor may be partitioned into two segments. We can distinguish first of all the properties of the hydrographic environment, which on the central Oregon shelf vary seasonally under the influence of upwelling. We can also distinguish the properties of the substrate, or the surface layers of bottom sediments, which in this study do not appear to vary from season to season. The major goal of this project is to determine the relative ecologic importance of the sediment versus the water with respect to foraminiferal faunas.

To determine the effects of the environment on the living foraminiferal fauna, and to sort out the ecologic parameters in order of importance (Krumbein, 1959), the several faunal parameters (Table 9) calculated by SYNECOLOGY for each sample were successively used as the dependent variable in a stepwise multiple regression analysis. The analysis attempted to correlate the variation of the parameter with the variations of several environmental variables. The input data consisted of faunal parameters and ecologic measurements from all stations except SG-10, the upper slope station.

Table 9. Statistical comparison of Oregon shelf benthic foraminiferal parameters from Sea Grant samples. Data do not include SG-10 (upper slope station) nor the second drop at 6911-2. Data calculated from 80 samples.

Parameter	Mean	Standard deviation
Total count of benthic forams in 20 cc	166.75	140.268
Total count of agglutinated forams	47.425	32.185
Total count of hyaline benthic forams	117.638	114.393
Percent agglutinated forams in benthic fauna	36.759	21.171
Percent hyaline forams	62.538	20.838
Ratio of hyaline/agglutinated forams	2.732	2.220
Diversity (Simpson) of benthic forams	0.838	0.096
Diversity (Shannon) of benthic forams	2.415	0.474

Missing ecologic data were estimated as accurately as possible since the computer read data blanks as valid data with a value of zero.

Diversity Measurements. The species diversity of a population is a characteristic of that population and not of any of the species that comprise the population (Williams, 1964). Thus it can be used to describe a fauna or to indicate differences between two faunas. In addition, gradients in species diversity can yield information about the effects of predation (Paine, 1966; Spight, 1967), preservation (Berger and Parker, 1970), gradients in the physical-chemical environment (Gibson, 1966; Beerbower and Jordan, 1969) and several other factors (Pianka, 1966).

However, a problem exists in the choice of an appropriate index of diversity. A usable index should allow the comparison of samples over a considerable range of density, or numbers of individuals in the total population. Many diversity indices have been reported in the literature, but none of them are completely independent of sample size.

For many purposes, the simple count of the number of species present in the sample can be an adequate diversity index (MacArthur, 1965; Stehli, 1965; Berger and Parker, 1970), especially for environments where many species regularly occur but in low abundance (Pianka, 1966). Sanders (1968) has proposed a "rarefaction method" of diversity analysis; Sanders claimed that each environment had its own characteristic rate of species increment, which produced "environmental bands" on the graph of the number of species versus the number of individuals.

Most diversity studies require the calculation of an index. The rate of species increase as additional samples are taken from the same population has been used as an index by Fisher, Corbet and Williams (1943) and Margalef (1957):

$D_m = (S - 1)/\ln N$, where N is the total number of individuals in the population and S is the total number of species

$D_f = \alpha$ when N = 0 in the equation

$$S = \alpha \ln (N/\alpha + 1)$$

D_f values tend to stabilize at low faunal densities while D_m is greatly influenced by sample size at low densities; however, D_f varies with density in more diverse samples (Sanders, 1968). A coefficient of the next probable occurrence has been devised by Simpson (1949) and modified by Williams (1964) to provide a diversity coefficient:

$D_p = 1 - (\sum_{r=1}^{S} P_r^2)$ where P is the percent abundance of the species in the fauna

However, Simpson's index is very dependent on the relative abundance of the more abundant species and takes into little account the rare species (Williams, 1964, p. 147). On the other hand, Simpson's index has a low rate of change with increasing sample size (Sanders, 1968). McIntosh (1967) provided a diversity index that was a special case of the distance formula:

$$D_d = 1 - \sqrt{\sum_{i=1}^{S} n_i^2}$$ where n is the number of specimens of that species

However, McIntosh himself showed that the value of the index was dependent on sample size, as N specimens were added, the value of the index increased at some rate between zero (all one species) and $N - N^{1/2}$ (each specimen a new species). The information theory index (Shannon's index) is influenced by both species and dominance differences:

$$D_h = -\sum_{r=1}^{S} P_r \log(P_r)$$

With increasing density, Shannon's index very rapidly reaches a stable value (Sanders, 1968). In addition, if the environment can be quantified, the information theory index can be used to measure the diversity of the habitat, thus allowing direct comparison with that of the population (MacArthur, 1965).

In his review of diversity indices, McIntosh (1967) concluded that the three indices of diversity (D_h, D_p and D_d) had similar dependence on sample size and that there was no _a priori_ reason why any one should be preferred. Sanders (1968) considered that Shannon's index (D_h) had sufficient stabilities at densities greater than 100 to allow direct comparison of samples of different densities. In the

Table 10. Benthic foraminiferal faunal diversity, seasonal stations. Samples arranged by depth class, station and cruise.

Cruise	Depth (m): 75	100		125	150	200		450
	Station: SG-22	-7	-15	-26	-6	-2	-8	-10
6808	1.36			1.74				
				2.48				
				2.24				
6810	1.52		2.09					
6901	1.77					1.33	2.42	
	1.36					1.20	2.64	
	1.11						1.82	
6904		2.34	2.58	2.46	2.69	2.39	2.17	2.56
		2.80	2.51	2.65		1.99	2.47	2.79
		2.45	2.58			1.86	2.69	2.80
6907	2.05	2.27	2.99	2.74	2.85	1.82	2.60	2.36
	2.04	2.63	2.85	2.73	2.77	2.06		2.18
	1.51			2.76	2.64	2.25		
6910			3.04			2.52	2.39	
			2.92			2.30	2.54	
							2.66	
6911	2.21	2.93	2.84	2.29	2.84	2.43	2.60	2.73
	1.96	2.65	2.88	2.34	2.74	2.62	2.57	3.03
	1.85	2.43		2.51	2.98	2.94	2.47	2.76

author's opinion, Shannon's index appears to be the most useful, both from the point of view of having stable values over a considerable density range (Sanders, 1968), and from the point of view of having the least spread between maximum and minimum values at densities less than 100 (McIntosh, 1967).

The results of faunal diversity analysis (Shannon's index) show a consistent faunal diversity in the range of 2.5 to 3.0 for the stations deeper than 100 m (Tables 10 and 11). The 75-m station (SG-22) has diversities generally between 1.5 and 2.0. The differences in diversities appear to represent the differences in faunas indicated by the index of faunal affinity discussed above.

Table 11. Benthic foraminiferal faunal diversity, 6911 supplementary stations.

Water depth (m)	Station	Diversity
125	SG-25	3.24
		2.85
		2.74
150	SG-9	3.03
		2.97
		2.97
200	SG-2*	2.44
		2.56
		2.14

*These data are from the second of two drops taken at this station at this time. Diversity data from the first drop are presented in the previous table.

<u>Stepwise Multiple Regression Model</u>. It is obvious that each environmental factor measured is not of equal importance to the occurrence or abundance of any one species, or to the size or diversity of the total standing stock. Stepwise multiple regression is an analytical method of "sorting out" the independent variables that exert the major portion of control over the dependent variables (Krumbein, 1959). The analysis yields a sequence of variables ordered in descending contribution of the independent variable to the variance of the dependent variable.

The analyses were performed by the OSU Computer Center library program "*STEP" (Yates, 1969). This program uses both "step up" and "step down" methods (Snedecor and Cochran, 1967, p. 412) to generate the multivariate regression equation; it does not examine every possible subset.

By proper formulation of case parameters, it is possible to use *STEP to generate trend surface equations from the linear to any desired higher order. Trend surfaces have the advantage of reducing the noise level of raw data (Agterberg, 1964, p. 114). The trend surface itself may reveal a functional relationship (Miller, 1956), or the deviations from the trend surface (the residuals) may yield important relationships (Merriam, 1963; Stehli, 1965).

For the multiple regression determination of the ecologic controlling factors for species abundance, specimen size and various faunal parameters, the following linear model was used:

$$Y = A + BX_i + CX_i^2 + DX_j + EX_j^2 + \ldots + E,$$

where Y, the dependent variable, was the counted number of individuals, or the log of that count, or the percent of the species in the living fauna at that sample, or a calculated parameter. The independent variables (X_i, X_j, . . .) were the measurements of the physical and chemical environment that were made at the time of collection. The measurement and its square were used to test for curvilinear relationships.

The regression error (E) in the above model merits special note. Large values of the regression error may have come from two different sources. First, the species or parameter may not be controlled by one of the ecologic factors measured; i.e., its limiting factor is some undetermined element of the environment. Alternately, the variability in abundance of specimens in adjacent cores introduced considerable variation in the dependent variable without any corresponding variation in any of the independent variables measured. Thus, while the regression error may tend to diminish as the regression progresses, it can never reach zero; i.e., the regression surface cannot perfectly fit the data.

Combined Data, Shelf Stations. The results (Appendix V) indicate that not all faunal parameters can be statistically explained by the environment. Some faunal parameters (count of living agglutinated foraminifers, the hyaline/agglutinated ratio and diversity (Simpson) of total living benthic foraminifers) do not show a strong dependence upon any measured ecologic variable; these may depend more upon some biologic factors rather than on the physical-chemical environment.

However, some other faunal parameters do show a strong dependence upon measured ecologic variables. Percent living agglutinated foraminifers and percent living hyaline foraminifers both show a strong dependence upon ecologic variables measured from the sediment. Dependence upon the water column, or upon seasonally changing factors, is almost nil. Diversity (Shannon) of total living benthic foraminifers depends almost entirely upon other faunal parameters.

Two faunal parameters are surprisingly mutually related. The count of living hyaline foraminifers and the count of total living foraminifers both have very similar ordered sequences of independent variables and identical corresponding R^2 values. The two parameters have a mutual simple correlation coefficient (r) of 0.986. The numbers of living hyaline and living total benthic foraminifers vary in similar ways along gradients in median grain size (Figure 24) and water depth (Figure 25). Almost all of the variations in faunal total standing stock are due to the variation in the size of the hyaline standing stock.

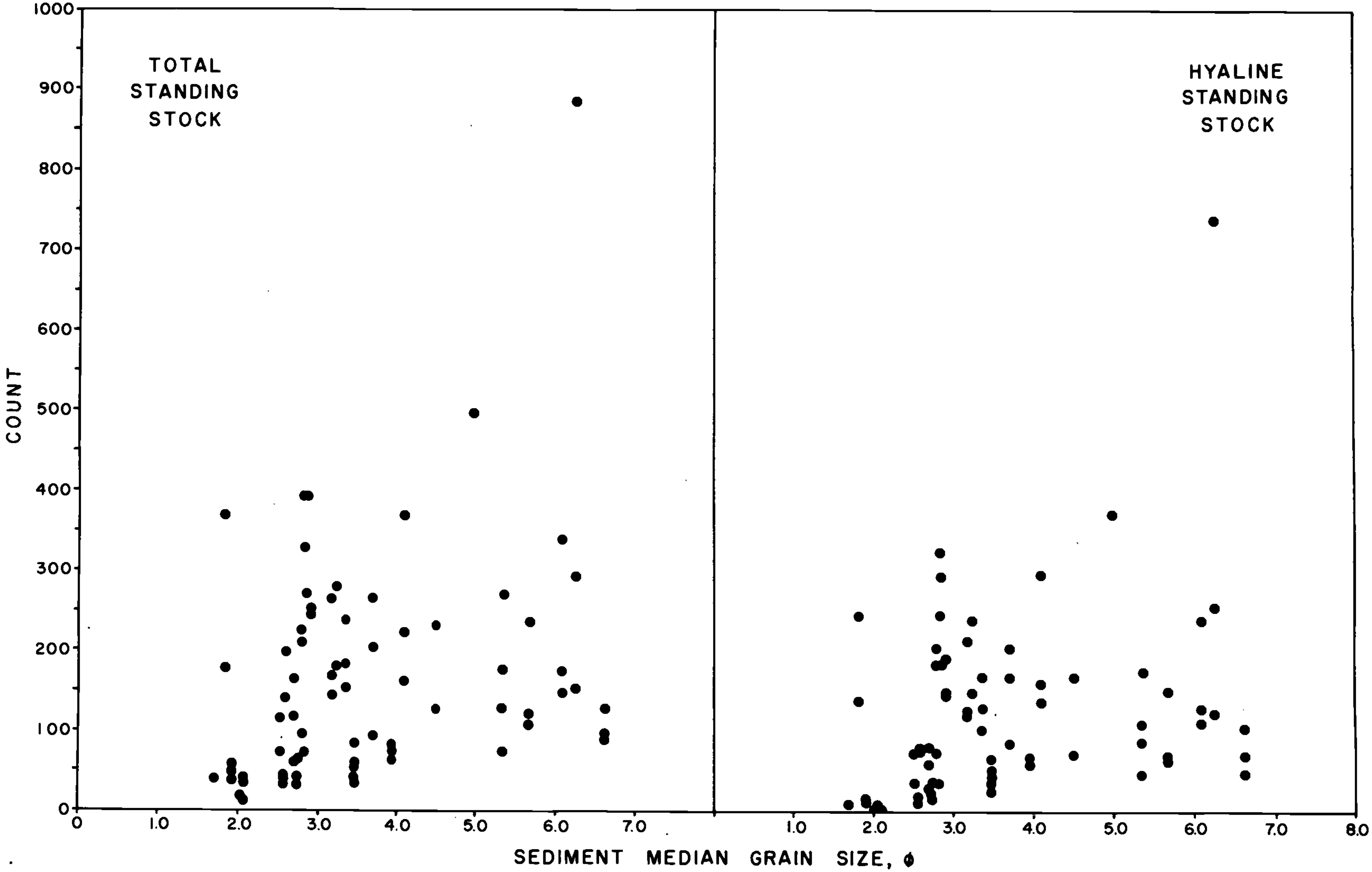

Figure 24. Variation in standing stock with variation in sediment.

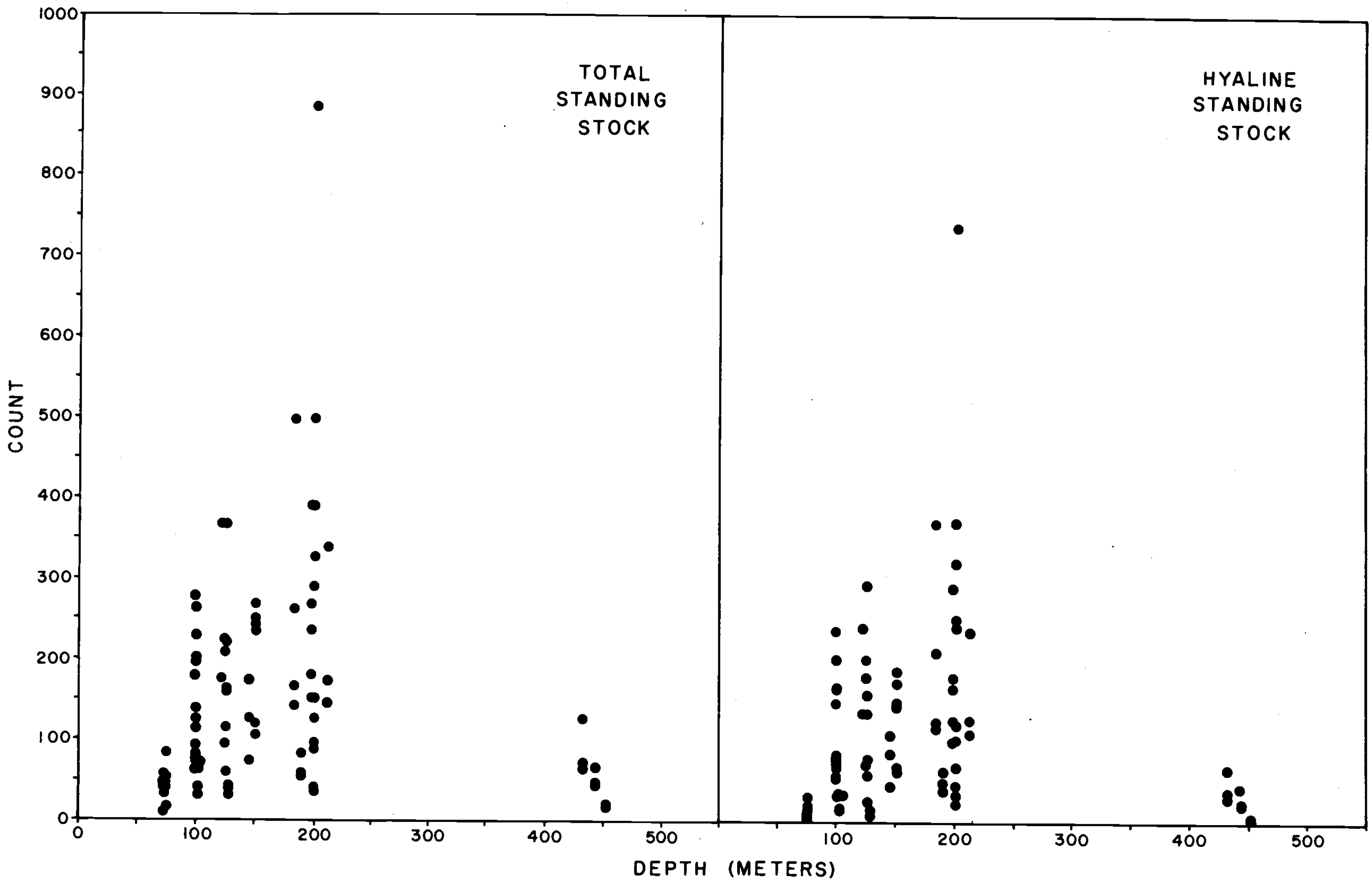

Figure 25. Variation in standing stock with variation in depth.

While it has been shown above that the lognormal distribution does not fit the species frequency distribution for most samples, there is some evidence that faunas may be lognormally distributed over ecologic gradients. The count of living benthic foraminifers has a much better fitting regression surface when the $\log_{10}$ (count) is used as the dependent variable; the same is true for the count of living hyaline foraminifers. In both cases, the ordered sequence of environmental variables for the count is different from that for the $\log_{10}$ (count).

Individual Shelf Stations. The regression analysis performed on the combined data was also repeated for the data from individual stations. The individual analyses were done to determine if ecologic conditions and faunal responses were different at the different stations. The low number of samples examined in each case permits less confidence in the statistical results. However, the author considers it necessary to examine each station individually. Each station was originally picked to represent a different facet of the shelf benthic environment. Ecologic trends at one station need not be the same as those at another station, nor of the combined data.

In general, the foraminiferal faunal parameters responded differently to changes in the environment at each station (Appendix VII). Faunal standing stock and gross composition (i.e., percent hyaline specimens) depended heavily upon sediment carbon content for the shallowest station (SG-22) and on water phosphate content or median grain size (ϕ) for station SG-8. At station SG-15, the total and hyaline standing stocks depended upon variations in the water depth and in the percent carbonate of the sediment at the time of collection, but the agglutinated standing stock depended more upon the variations in water oxygen concentration. At station SG-2 the total and hyaline standing stocks depended upon the sediment percent sand and the standing stock of agglutinated foraminifers depended upon the percent calcium carbonate in the sediment. Diversity functions of the total living fauna usually depended upon other faunal parameters, but they did respond to the variation of some ecologic functions, especially at station SG-15.

The shallowest station, SG-22, presented a consistent correlation between one measure of the environment and the foraminiferal faunal parameters. All faunal parameters except the diversity parameters have a high level of correlation with either the total carbon or the organic carbon content of the sediment (Figure 26). Organic carbon content of the sediment accounted for 57% of the variability in the standing stock of all living foraminifers and 80% of the variability in the standing stock of living hyaline foraminifers. Sediment total carbon accounted for 76% of the variation in the fraction of living hyaline foraminifers and 73% of the variation in the hyaline/agglutinated ratio.

The second dependent variable to have been sorted out for its

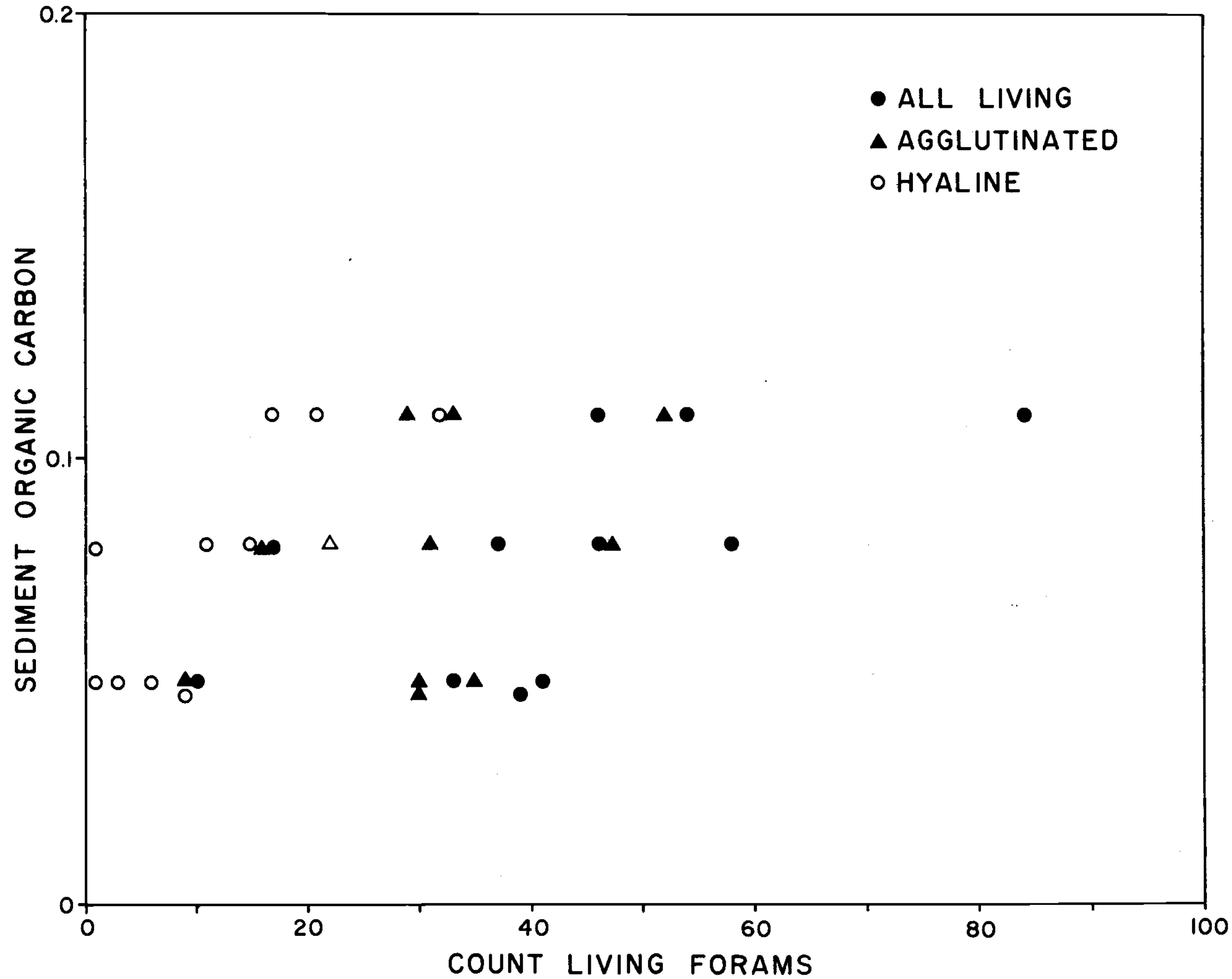

Figure 26. Variation in standing stock with variation in percent organic carbon of sediments at SG-22.

contribution to the variation in foraminiferal faunal parameters at SG-22 is of interest. In all cases, it is a sedimentary parameter, indicating that some change in the sediment is responsible for the change in food (carbon content) or texture actually measured. The inverse relationship between percent clay and the standing stock of agglutinated and hyaline foraminifers, and the direct relationship between percent sand and the common log of either the total standing stock or the hyaline standing stock both indicate that lower numbers of individuals are found in samples with smaller grain sizes. In theory higher numbers of individuals would be expected; this may be simply a dilution effect, or there may be a lag effect between the influx of fine sediments with abundant nutrients and foraminiferal response by reproductive increase in numbers.

Data from two stations were combined in a special test of station ecologic individuality. Stations SG-6 and -8 are close together on the sea floor. The sediments are similar, and they have a high average index of faunal similarity. If there is a general faunal response to a change in the environment, these two stations should respond alike, and the response should parallel that of the combined data.

The regression analysis results from the two stations indicated the existence of some general trends. The standing stock of hyaline foraminifers depended upon variations in water depth, both for the two stations and for the combined data. Likewise, the gross composition of the fauna depended upon water depth for the data from the two stations and for the combined data.

However, there were differences. The total standing stock and the standing stock of agglutinated foraminifers for the two stations depended upon the median grain size, which was not the case for the combined data.

Species Association

Using data for the total (live + dead) fauna, Boettcher (1967, p. 35-47) found some associations of species when he established bathymetric faunas by grouping species with similar depth distributions. He expected that the faunal groups would have paleoecologic applications. He noted that there was a progression from fauna to fauna along the depth gradient and that a few species had such a broad depth distribution that they were found in all faunas. He also noted that the depth at which a particular faunal boundary occurred was not the same in each of his three traverses.

The author considers that the examination of the co-occurrence of living specimens of species pairs is a better approach from an ecologic point of view. The living fauna is considered to be responsive to the modern environment; the total fauna may reflect the effects of selective destruction and transportation of empty foraminiferal tests.

The interaction of a species with its environment, both biologic and physical-chemical, is considered too complex to evaluate using the distribution of several species along a single ecologic gradient.

Many authors have investigated the problems of determining which species in a large collection of samples are consistently associated with each other. The problem is to determine which species frequently are part of each other's biologic environment (Fager, 1963, p. 420) and which are merely accidental associations. Both Jacard (1912) and Sørensen (1948) developed indices based on the average proportion of joint occurrences; these indices were criticized by Fager (1963, p. 420-421) for not taking into account the number of occurrences, among other reasons. Cole (1949) attempted to determine the significance of species-species associations using a 2 x 2 contingency table with a X^2 test to determine if the observed number of joint occurrences departed significantly from the number expected under the assumption of independent distribution of the two species. Fager (1957) criticized Cole's methods on the basis that little or no evidence of association would be shown by two species that occurred in most of the samples. At that time, Fager proposed an index of affinity between pairs of species that could be tested for significance by the t-test; later Fager (1963) proposed a new index. He used the new index to determine groups of zooplankton species that corresponded with specific water masses (Fager and McGowan, 1963).

Once coefficients of species affinity have been calculated for each species pair, it is convenient to display them in a trellis diagram (Fager, 1957). The number of affinities and recurrent groups can then be determined.

In this study only those species found in 20 or more samples were tested for affinity. This resulted in a matrix of 39 species, with a total of 1, 731 occurrences. Although this is considerably less than the total number of species found living (146 species, plus a few unidentified juveniles and fragments), the occurrences represent the major portion of the total occurrences (approximately 2, 300). Thus, this lower number of species, although arbitrarily determined largely by the cost of computer time, should still define the recurrent groups of Oregon outer shelf benthic foraminifers.

The benthic foraminiferal species consistently present in the samples from the Sea Grant stations can be grouped into a natural faunal unit. Recurrent group analysis (Table 12) shows that there is only one group of foraminifers that are consistently part of each other's biologic environment. This "natural faunal unit" includes 15 species that have coefficients of association (Fager, 1963) consistently higher than 70 (Table 13). Other species are less consistently part of this biologic environment. Certain species (e.g., Gaudryina arenaria, Buliminella elegantissima, Cibicides lobatulus and Loxostomum pseudobeyrichi) come from other biologic environments, which

Table 12. Recurrent group analysis for all possible species pairs based on species with more than 20 occurrences

Species	Number of Occurrences	Coefficient																																						
Hippocrepina sp. 2	29	-																																						
Dendrophyra arborescens	24	34	-																																					
Saccammina difflugiformis aernulata	55	50	41	-																																				
Ammodiscus minutissimus	31	53	33	51	-																																			
Reophax micaceous	38	36	46	55	35	-																																		
Reophax nanus	41	23	35	59	42	36	-																																	
Reophax scorpiurus	25	33	49	46	29	52	44	-																																
Reophax subdentalinaformis	31	33	33	41	36	64	34	47	-																															
Nouria polymorphinoides	43	34	53	58	38	62	57	55	56	-																														
Adercotrema glomerata	48	40	44	55	44	52	43	41	49	57	-																													
Recurvoides turbinata	36	43	41	47	45	35	55	40	30	59	55	-																												
Thalmanammina parkerae	67	52	57	63	53	65	61	59	59	76	71	69	-																											
Cribrostomoides columbiensis	62	50	52	56	48	64	54	51	57	72	64	59	84	-																										
Spiroplectammina biformis	43	45	44	58	44	45	64	40	47	59	59	64	73	68	-																									
Textularia earlandi	46	30	51	51	40	62	51	44	50	65	62	52	74	75	59	-																								
Texturlaria sandiegoensis	46	41	51	50	42	62	44	53	56	65	62	57	72	77	63	74	-																							
Trochammina pacifica	49	42	41	60	56	53	46	46	44	57	68	67	70	64	59	63	61	-																						
Trochammina sp. (thin walled)	31	27	33	48	26	52	45	43	45	63	42	39	61	62	49	56	58	44	-																					
Gaudryina arenaria	28	46	27	41	54	12	50	23	14	35	41	54	46	46	46	28	28	54	20	-																				
Eggerella advena	76	51	49	76	52	63	66	46	56	70	66	59	80	80	67	74	71	67	60	46	-																			
Quinqueloculina stalkeri	30	31	45	44	30	59	37	51	59	50	50	37	63	63	53	62	59	44	43	7	59	-																		
Lagena distoma	37	28	40	51	41	45	62	43	37	63	55	58	64	59	63	58	58	58	38	37	62	54	-																	
Fissurina marginata	21	28	27	41	24	35	34	39	43	43	32	26	51	55	50	45	52	37	35	17	48	52	50	-																
Buliminella elegantissima	20	33	18	45	28	18	52	22	12	27	26	34	33	28	38	20	20	22	28	25	46	16	26	20	-															
Brizalina pacifica	79	52	55	70	51	69	58	54	63	70	70	62	88	87	67	75	75	17	59	45	84	62	65	52	33	-														
Globobulimina auriculata	50	55	49	61	48	57	51	51	46	60	53	57	74	77	59	63	65	63	51	35	71	57	63	56	35	76	-													
Globobulimina pacifica	38	36	43	55	26	61	46	52	58	59	49	54	69	68	60	69	65	53	50	15	67	62	64	57	25	69	73	-												
Uvigerina juncea	70	56	56	66	47	71	56	57	64	77	69	62	89	85	70	74	78	68	62	36	82	63	67	55	29	93	76	74	-											
Trifarina angulosa	43	43	44	51	58	42	36	31	49	49	64	54	63	58	54	41	54	65	27	46	58	45	50	40	24	69	56	32	64	-										
Epistominella exigua	69	56	57	63	50	68	55	58	58	75	73	62	90	81	68	78	75	72	63	48	80	62	61	50	27	88	72	64	88	64	-									
Eilohedra levicula	50	42	49	55	48	67	42	42	58	67	69	57	76	75	58	77	80	67	56	35	76	64	60	49	16	78	60	60	79	56	77	-								
Loxostomum pseudobeyrichi	23	27	26	42	23	51	16	29	52	41	48	17	54	45	38	43	50	36	41	0	45	53	21	41	14	54	35	27	55	45	55	53	-							
Globocassidulina depressa	37	49	30	49	50	32	46	23	24	25	45	36	42	50	40	46	47	49	21	56	57	27	38	25	44	50	42	27	41	43	53	47	17	-						
Globocassidulina subglobosa	38	33	40	55	41	61	53	58	52	62	49	57	69	66	65	62	67	56	55	25	63	17	67	57	33	68	69	71	72	45	66	64	37	35	-					
Florilus auriculus	43	37	47	49	41	42	50	34	36	44	57	51	57	56	61	56	54	55	44	49	63	45	55	37	41	64	50	35	57	51	66	58	38	63	50	-				
Florilus scaphus basispinatus	67	50	55	66	51	65	61	59	61	78	62	61	88	84	71	74	72	65	61	42	80	65	68	53	38	88	71	69	89	60	85	76	51	48	71	65	-			
Nonionella turgida digitata	56	42	55	63	38	69	54	56	58	65	58	54	82	76	67	69	73	59	60	25	72	66	62	53	36	83	76	72	85	53	77	66	53	37	82	57	80	-		
Nonionella stella	68	50	52	65	46	65	64	56	57	76	58	61	83	82	67	73	70	64	65	41	82	60	66	50	43	86	74	71	86	50	83	74	43	52	73	61	90	81	-	
Nonionellina labradorica	43	28	47	54	30	57	67	49	52	72	51	59	75	66	61	65	61	48	49	26	67	59	70	53	34	72	67	74	75	47	70	58	29	28	69	47	76	71	76	-

Table 13. Foraminiferal species of the Oregon Outer Shelf Fauna; a list of species with the highest coefficients of association as determined by recurrent group analysis.

Species	Coefficient
Thalmanammina parkerae	
Cribrostomoides columbiensis	
Eggerella advena	
Brizalina pacifica	
Uvigerina juncea	
Epistominella exigua	
Florilus scaphus basispinatus	
Nonionella stella	
Nonionella turgida digitata	
	80
Textularia earlandi	
Textularia sandiogoensis	
Globobulimina auriculata	
Eilohedra levicula	
Globocassidulina subglobosa	
Nonionellina labradorica	
	70

this study did not sample sufficiently for their recurrent groups to show on this analysis. Other species (e.g., Fissurina marginata, Spiroplectammina biformis) are scattered in occurrence.

Comparison of this "natural faunal unit" with the faunas of Boettcher (1967, p. 37) indicates that the Oregon outer shelf fauna contains representatives of three bathymetric faunas. Nonionella stella and N. labradorica are indicative of Boettcher's Fauna B (50-100 m). Eilohedra levicula and Textularia earlandi are indicative of his Fauna C (100-175 m). Brizalina pacifica, Eggerella advena, Epistominella exigua, Nonionella turgida digitata and Uvigerina juncea are indicative of his Fauna D (175-399 m).

The differences in the faunal groupings between this study and that of Boettcher (1967) may be attributed to two factors. Firstly, different faunas were studied; the author studied only the living fauna; Boettcher studied principally the total fauna. Secondly, the sampling programs of the two projects were different; the author studied seasonal collections at selected stations, with most stations within the depth range of 100-200 m. Boettcher studied samples collected on one cruise from three traverses, with a depth range of 17-350 m.

Autecology

The autecology portion of this study deals with the response of individual species in terms of abundance and size distribution to the measured physical and chemical environment. The species selected for consideration are the dominant species of the Oregon outer shelf community as determined above by recurrent group analysis, plus a very few additional species of special interest.

Fundamental Niche

The concept of the fundamental niche (Hutchinson, 1957) is useful in foraminiferal autecology. This modification of the ecologic niche was defined by Hutchinson as an n-dimensional hypervolume of ecologic variables in a rectangular coordinate system. The fundamental niche of a species is contained within the upper and lower limits of tolerance of that species for each ecologic variable; hence the fundamental niche of a species can be defined, measured and distinguished from that of other species. Thus, for example, the fundamental niche, based on the reproductive limits of tolerance, of *Ammonia beccarii tepida*, is bounded by temperature limits of 20-30°C when the salinity is at 33.5‰ and by salinity limits of 13-40‰ when the temperature is 24-27°C (Bradshaw, 1957, 1961). Unfortunately, only a few intertidal foraminiferal species have been examined sufficiently well to allow a reasonable delimitation of their fundamental niches.

The ecologic niche is much more difficult to define and distinguish. According to various authors, the niche is: 1) the sum total of all the ecologic requisites and activities of a species (Kormondy, 1969, p. 103); or 2) the role that an organism plays in an ecosystem (Odum, 1963, p. 27).

The fundamental niche concept is used in the discussion of foraminiferal autecology because of the extreme difficulty in determining the ecologic niche of a foraminiferal species. The large numbers of foraminiferal species in the same apparently uniform sample causes problems in ecologic evaluation. From an ecologic point of view, if closely related species occur together there must be some difference in energy source utilization, seasonal or diurnal periods of activity, time of reproduction, etc., so that the species occupy different niches (Odum, 1963, p. 100). Yet for most collections of living foraminifera, it is most fortunate if we have accurate values for gross ecologic variables (water depth, sediment median grain size, temperature and salinity). For most foraminiferal species, the questions of accurate niche assignment and microhabitat cannot be answered.

In the present study, it is not possible to define the fundamental niche of each species by known upper and lower limits of tolerance. The limits of tolerance must be approximated statistically from the measured abundance of each species under the various ecologic conditions.

Computerized data processing has allowed the approximation of the limits of tolerance. Program *STEP conveniently provided for each ecologic variable the average of that variable for the occurrences of a species, and also the standard deviation of that average. The above average and standard deviation are calculated as if the species had a frequency of one at each occurrence; a slight amount of additional programming and calculation yielded the average for each variable weighted by the absolute abundance of the species at each occurrence. If we assume a normal distribution of specimens of a single species within the limits of tolerance of the species, then the average and standard deviation can be used to approximate the limits of tolerance of that species. Environments beyond these limits would not be optimum and might be lethal.

The assumption of a normal distribution over the range between the limits of tolerance has not been statistically tested. However, comparison of the average of occurrences with the weighted average will provide a subjective test. A large difference between the two averages would indicate that either the distribution is highly skewed, or the sampling program did not sample the species over its entire ecologic range. The two explanations need not be mutually exclusive.

Therefore, in this study the first approximation to the fundamental niche of a species is taken to be an n-dimensional hypervolume in a rectangular coordinate system, with the limits of a particular variable determined by the average for the occurrences of the species, plus and minus one standard deviation. The deviation of the weighted average from the average of occurrences is a measure of the validity of the limit approximations. The data for each species are presented in the form of the averages and the standard deviation (Appendix VII) rather than in the form of upper and lower limits.

Limiting Factor Analysis

The use of regression analysis for the sorting out of ecologic variables that control the abundance of a single species depends upon the concept of limiting factors. A limiting factor is the ". . . weakest link in the ecologic chain of requirements. . ." (Odum, 1963, p. 65) of a species. When this essential factor is in short supply, growth is limited; growth increases as the supply of the limiting factor increases. This is true whether the limiting factor is needed in bulk or in trace quantities. Thus, if a species has variations in local abundance or rate of growth that correlate closely with variations in supply of some ecologic factor, then the factor can be presumed to be limiting.

Multiple regression analysis has been used previously to examine complicated multivariate situations for limiting factors. McIntire (1968) has fit regression response surfaces to the relative occurrence of each of 21 algal taxa. Buzas (1969) studied the effects of periodicity and variations in temperature, salinity, oxygen and chlorophylls on the abundance of three foraminiferal species at three estuarine stations. In a study of beach firmness, Krumbein (1959) found that moisture content, average grain size and sorting were "first order" independent variables.

In evaluating the results of the regression analysis (Appendix IX), the author has established the convention that variables entered at early steps and later deleted are "second order" variables, along with variables whose coefficient for the maximum fitting surface is not significantly different than zero. Also, if the addition of a variable does not produce an increase in R^2 greater than about 5%, then that variable is a second order variable. Therefore, first order variables are those that 1) are in the regression equation at the best fit of the regression surface to the data; 2) have coefficients significantly different than zero; and 3) contribute more than 5% to the value of R^2.

Even though most of the species tested for limiting factors are members of the Oregon outer shelf community, there is no consistent dependence upon either the substrate or the water column. There appears to be a slight tendency for water properties to be more often limiting factors for the standing stock of a species while sediment properties are more often limiting factors for percent abundance.

In most cases, the absolute or relative abundance of the individual species is dependent upon a "set" of first order variables (Buzas, 1969) rather than upon any single variable. In addition, different sets of first order variables are found for the absolute abundance and the relative abundance of a single species. The first order variables for the absolute abundance of Saccammina difflugiformis arenulata are water depth and three sediment grain size parameters (average ϕ, clay % and silt %), and those for its relative abundance are water oxygen content and sediment percent sand. The counted abundances of Cribrostomoides columbiensis, Eggerella advena, Uvigerina juncea, Florilus scaphus basispinatus, Nonionella stella and Nonionellina labradorica depend upon their own sets of first order variables from both the sediment and the water. The same is true of the first order sets for the percent abundances of C. columbiensis, E. advena, Textularia sandiegoensis, U. juncea, Nonionella stella and Nonionellina labradorica.

Only a few species have the entire set of first order variables taken from the water (Thalmanammina parkerae (count and percent), and Textularia sandiegoensis (percent)). In a few cases, there is only one first order variable (Brizalina pacifica (count), Epistominella exigua (count and percent), Florilus scaphus basispinatus (percent) and Nonionella turgida digitata (percent)). It should by now be evident that benthic foraminifers do not respond simply to a single limiting factor, but rather in a complex manner to multivariate fluctuations.

Some of the ecologic variables submitted for analysis are more frequently first order variables than are others. Temperature is often a first order independent variable; it appears to be a limiting factor for both the count and the percent abundance of Thalmanammina parkerae, Nonionella stella, Uvigerina juncea and Textularia sandiegoensis, and for the absolute abundance of Epistominella exigua. Salinity is a first order variable for both the absolute and relative abundances of Thalmanammina parkerae and Eggerella advena. Of the three nutrients measured in the water, phosphate concentration is a limiting factor more frequently than silicate or nitrate concentrations. The concentration of dissolved oxygen is important for a few species, especially Nonionellina labradorica (both absolute and relative abundance). The relative importance of the month of collection for the percentage of Cribrostomoides columbiensis is an indication of annual reproduction; the negative sign of the coefficient indicates that larger percentages are found in the winter and spring collections. (A quick scan of Appendix II shows that this is true at SG-15 and SG-26.) Sediment percent calcium carbonate is a first order variable for C. columbiensis (absolute abundance) and for Nonionella stella (percent abundance). Sediment percent sand, percent silt and percent clay are found several times as first order variables, whereas sediment sorting, average grain size and median grain size are found as first order variables only a few times. The organic carbon and organic nitrogen contents of the sediment appear several times as first order variables, but total carbon only once.

Individual Species

Saccammina difflugiformis arenulata. This coarse-grained agglutinated species is typical of the inner sublittoral, where sand-sized sediments predominate. Both the relative and absolute abundances are highly peaked for the medium sand grain-sized sediments and 75 m water depth; long tails of low abundance extend into greater depths and finer-grained sediments (Figure 27). The species may be very abundant in shallower water and on coarser-grained sediments, but this project did not sample that environment (see Lankford, 1962 and Boettcher, 1967). The non-normality of the distribution over depth and sediment gradients is probably responsible for the differences between the average of occurrences and the weighted averages (Appendix VIII). The regression analysis results (Appendix IX) for the absolute abundance also show the dependence of the species on water depth and grain size. The percent abundance increased with increases in percent sand and in water oxygen concentration; the latter is generally dependent upon water depth. The low numbers and percentages of individuals at greater depths and finer-grained sediments may result from negative biologic interactions or inhospitable physical-chemical conditions.

In other Pacific Coast foraminiferal studies, the species has been considered mostly in relation to its distribution over the depth gradient. Walton (1955) noted that living specimens were found from 9-457 m (5-250 fathoms), but were most common shoaler than 183 m (100 fathoms) and had a maximum abundance between 37 and 73 m

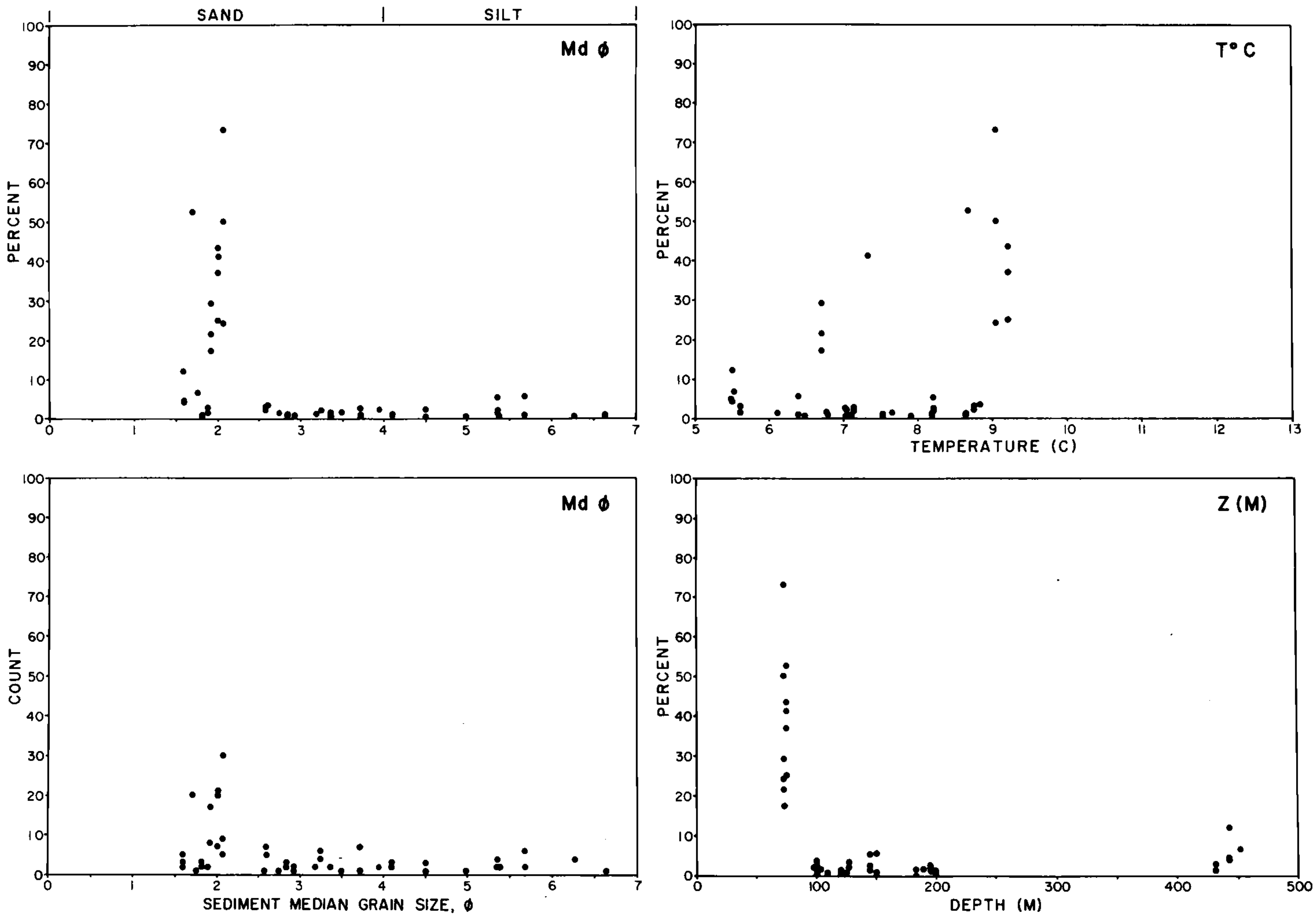

Figure 27. Ecologic gradient distribution of Saccammina difflugiformis arenulata.

(20-40 fathoms); he considered it characteristic of the Inner Bay Facies. Lankford (1962) found living specimens between depths of 9-46 m (30-150 feet), but considered it part of the Deep Fauna (depths greater than 30 m (100 feet)) on level sand bottoms. Boettcher (1967) considered the species indicative of Fauna C (100-175 m depth range).

Thalmanammina parkerae. This commonly occurring small-sized species has maximum relative and absolute abundances at 100 m, but high abundances over the depth range of 100-200 m. Both absolute and relative abundance maxima occur at 9°C, but there are many relatively high occurrences over the 6-8°C temperature range. Along the sediment median grain size gradient, maximum relative and absolute abundances are found in medium-grained sand, but there is a long tail of occurrences in the silt-sized grains. The general symmetry of occurrences on the ecologic gradients resulted in a general close agreement of averages and weighted averages (Appendix VIII); the approximations to the limits of tolerance are thus considered reliable. Regression analysis (Appendix IX) indicated that temperature and salinity were controlling factors for the absolute and relative abundances.

Cribrostomoides columbiensis. This species has a single maximum in absolute abundance at 125 m but several occurrences in high abundance at 200 m; it has a generally low relative abundance at all depths. On the temperature gradient, the absolute abundance maximum occurs at 6°C, but there are numerous occurrences over the temperature range of 6.5-8.5°C; the relative abundance maximum is at 7.5°C. The absolute abundance maximum on the median grain size gradient occurs in the medium-grained sands, as does the relative abundance maximum; in both cases there is a long tail of occurrences in the silt-sized sediments. In the estimation of limits of tolerance (Appendix VIII) there is general but not extremely close agreement between the average and the weighted average. Regression analysis indicates that three variables (sediment percent carbonate, water phosphate concentration and sediment sorting) are the first order variables accounting for 42% of the variation in absolute abundance; water phosphate concentration and two additional variables (month of collection and sediment median grain size) account for 31% of the variation in relative abundance (Appendix IX).

Eggerella advena. This species has its greatest relative abundance in medium-grained sand at depths of 75 m; Boettcher (1967) indicated that this species continued to have a high relative abundance in the living fauna in shallower waters. However, in this study, the maximum absolute abundance was found on medium-grained silts at depths of 150-200 m (Figure 28). On the measured temperature gradient, both absolute and relative abundances show maxima in the 6-9°C range. Close correspondence between the average of occurrences and the weighted average for most variables indicated that this

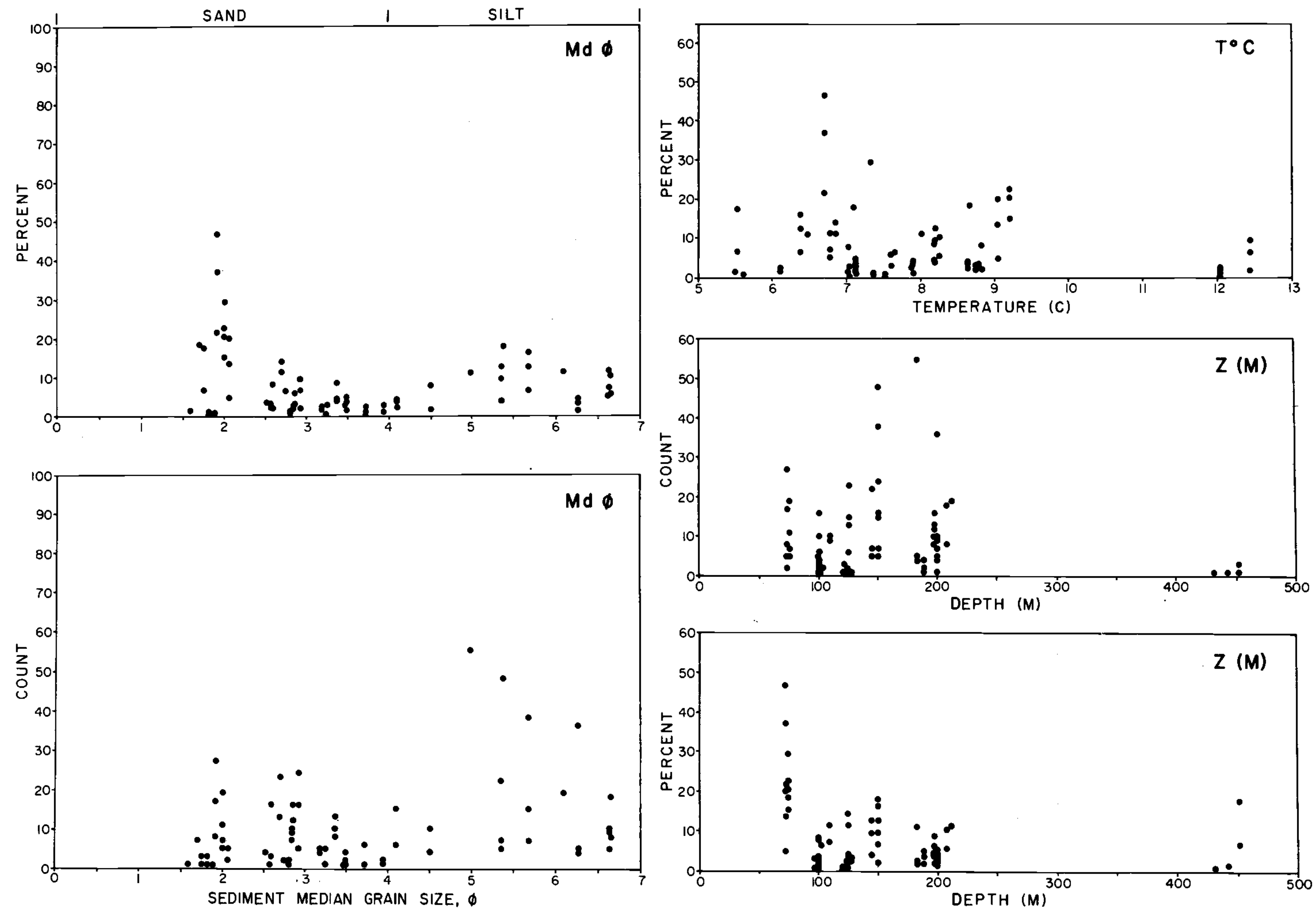

Figure 28. Ecologic gradient distribution of Eggerella advena.

project sampled most of the environmental range of Eggerella advena and that the estimated limits of tolerance are realistic (Appendix VIII). Regression analysis indicated a negative relationship between finer grain sizes and absolute abundance, and between sediment sorting and relative abundance. Both relative and absolute abundances increased with increasing salinity.

In an earlier study, Walton (1955) found the species living from 9 to 183 m (5 to 100 fathoms) with a maximum abundance at depths less than 18 m (10 fathoms); he considered the species part of the Inner Bay Facies. Bandy et al. (1964c) found that the species was dominant in the outer part of the shelf of San Pedro Bay especially between 20 and 70 m depth. Boettcher (1967) considered the species characteristic of Fauna D (175-339 m depth range).

Brizalina pacifica. Both the relative and absolute abundances have maxima on the fine-grained sand, but high abundances are found over the entire range of grain sizes sampled (Figure 29). On the depth gradient, maximum abundances are found at 125-200 m; the species may be abundant over the unsampled depth range of 200-450 m. On the temperature gradient, maximum abundances are found at 6-8°C. The generally close agreement between averages of occurrence and weighted averages (Appendix VIII) indicates a normal distribution over most of the ecologic gradients, with a resulting good approximation for the limits of tolerance. Regression analysis (Appendix IX)

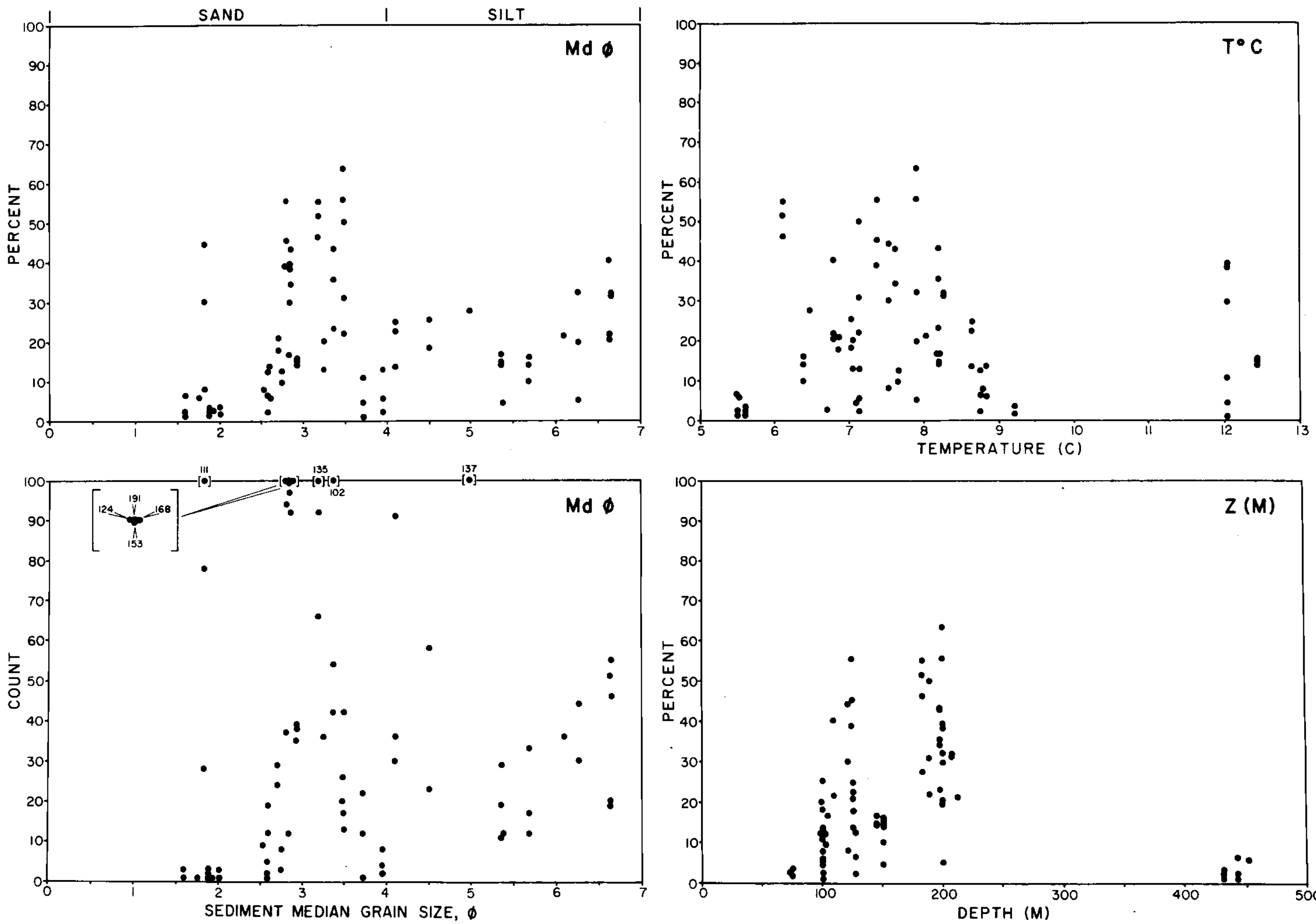

Figure 29. Ecologic gradient distribution of Brizalina pacifica.

indicated that the species has very little dependence upon any of the measured ecologic variables; 25 steps were needed to reach an R^2 value of 66% for absolute abundance and 21 steps were needed to reach an R^2 value of 69%.

The species is quite wide-ranging over the depth gradient. Walton (1955) found it living from 33-896 m (18-490 fathoms) with a peak abundance between 91-183 m (50-100 fathoms). Uchio (1960) found it living over a range of 18-1189 m (10-650 fathoms) with higher abundances from 91-732 m (50-400 fathoms). Boettcher (1967) found it living from 75-350 m with an abundance maximum at 125-200 m.

Uvigerina juncea. The counted number of specimens (Figure 30) is reasonably uniform in fine-grained sands and silt-sized sediments. On the depth gradient the absolute abundance is higher at 200 m, with no specimens found at depths less than 100 m. Percent abundance is uniformly low over gradients of sediment median grain size, temperature and depth. Comparison of the weighted averages and the averages of occurrence indicates a slightly skewed distribution; the species appears to be more abundant on the finer-grained sediments (Appendix VIII). Regression analysis (Appendix IX) indicated that temperature is important for both absolute and relative abundance, followed by the sediment percent silt and the organic nitrogen and carbon content in the sediment. It is most likely that this project has sampled only the upper portion of the depth range of this species.

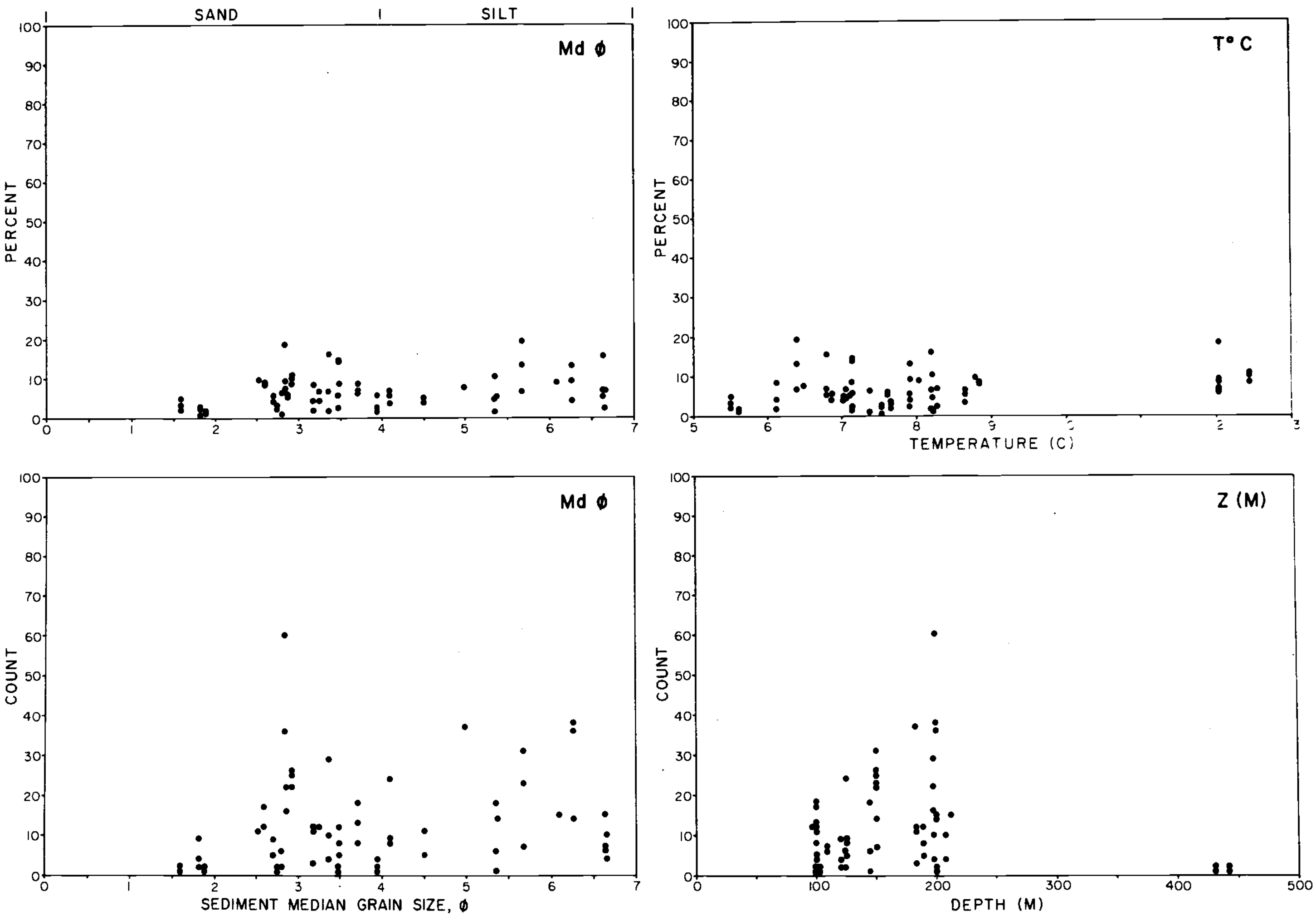

Figure 30. Ecologic gradient distribution of Uvigerina juncea.

Epistominella exigua. The species has abundance maxima at 200 m, and a more or less normal distribution over the temperature gradient. It shows a marked statistical preference for the finer grain sizes (Appendix VIII); median grain size in phi units accounted for 34% of the variation in percent abundance (Appendix IX).

Florilus scaphus basispinatus. The species has a slight tendency to have a maximum abundance at 100 m and in a fine-sand sediment (Figure 31). High absolute and relative abundances are found over the entire temperature range. Comparison of the weighted average with the average of occurrences (Appendix VIII) indicated that the species is normally distributed over most of the sampled ranges of ecologic variables; the limits of tolerance have most likely been well approximated. Regression analysis (Appendix IX) indicated that sediment properties are slightly more important than water properties.

Nonionella stella. On the depth gradient, maximum absolute and relative abundances were found at 100 m, but high occurrences were also found at 150-200 m. Maximum absolute and relative abundances were found on fine sand but with moderate abundances on finer-grained sediments. Both absolute and relative abundances range widely over the temperature gradient. The ecologic data (Appendix VIII) indicates that the species is slightly more abundant on the finer-grained sediments, but otherwise is more or less normally distributed over the measured ranges of ecologic gradients. Regression

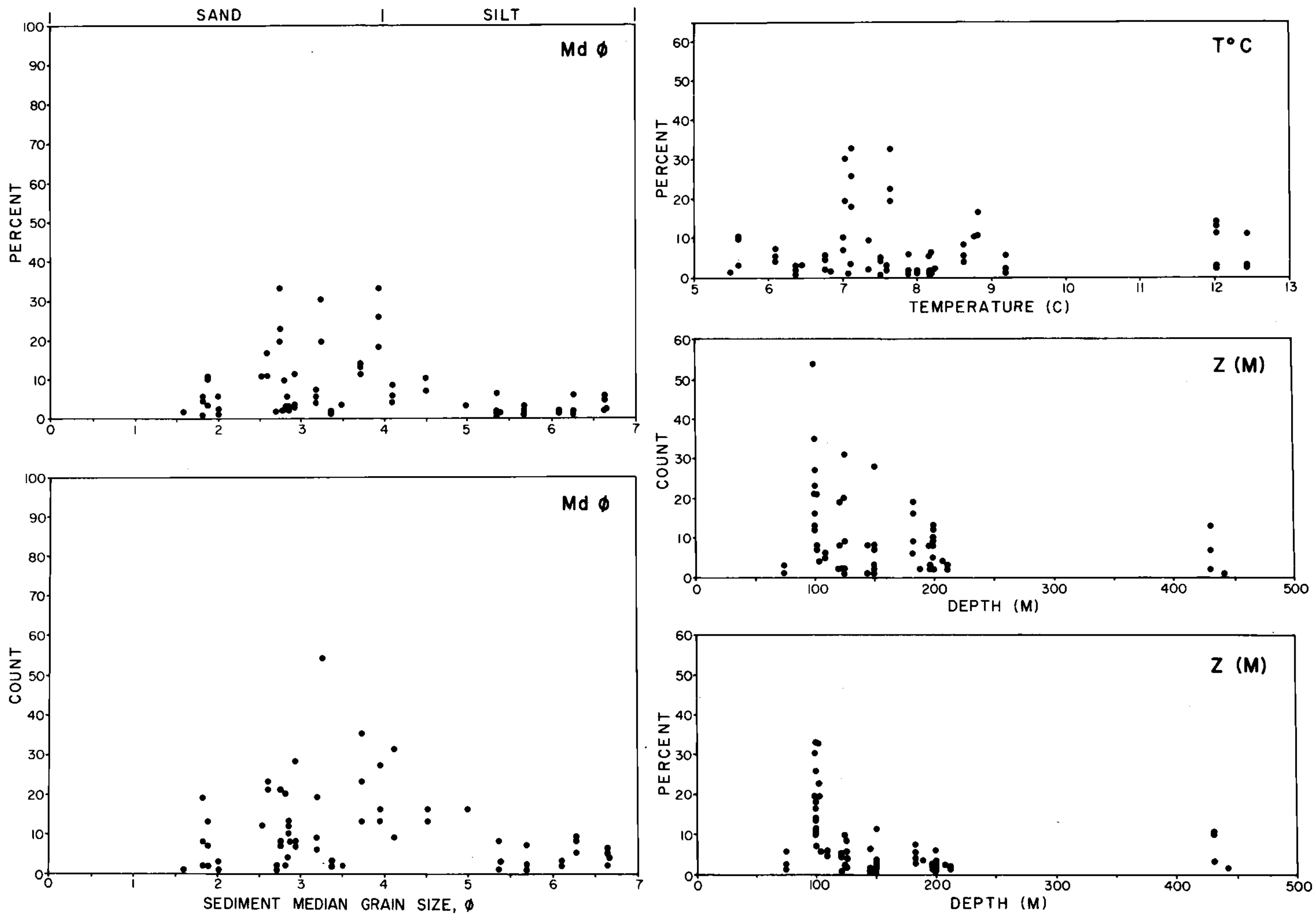

Figure 31. Ecologic gradient distribution of Florilus scaphus basispinatus.

analysis indicates that temperature is an important ecologic variable for both absolute and relative abundances; variation in temperature statistically accounted for 30% of the variation in absolute abundance (Appendix IX).

Nonionella turgida digitata. Maxima in both relative and absolute abundances were found between 8-9°C. On the sediment median grain size gradient, maximum relative abundance was found in the silt-sized sediments while maximum absolute abundance was found in the very fine sand-sized sediments, with many high abundances in the fine sand-sized sediments. Maximum percent abundance was found at 150 m, with many high abundances at 100-125 m. Maximum absolute abundance was found at 100-125 m, but with high abundances at 200 m depth. The ecologic data statistics suggest an absolute abundance distribution skewed toward greater numbers at shallower depths and at finer grain sizes (Appendix VIII). Regression analysis (Appendix IX) indicated that absolute abundance is dependent upon the water (water silicate and water phosphate concentration) and the percent abundance is dependent upon the sediment (percent sand).

Specimen Size

The test length of randomly selected individuals of selected species was measured to examine the influence of the environment on some species parameter other than abundance. Bandy (1963b) has noted that several foraminiferal species living at great depths increased in size with increasing water depth, with decreasing temperature, and with increasing oxygen concentration. Resig (1963) found that the median length of Eggerella advena decreased with increasing water depth and increased with increasing sediment grain size. In addition, Phleger (1955) found that in areas of rapid sedimentation, living populations of a single species tended to be large but individual specimens were small in size. Some measurement of the size of living individuals was therefore considered necessary to aid in interpreting the ecologic requirements of each species.

At each station, not all of the specimens of the selected species were measured. Only one of the three core samples was examined for specimen measurements. In addition, only the first 24 specimens of each selected species were measured. The subsample of measured specimens is considered to be an accurate representation of the size distribution of the entire population because: 1) the foraminiferal specimens (living and dead) and sediment grains were randomly distributed on the picking tray before examination under the microscope, so that all specimens of any one species had an equal chance of being measured, and 2) the core from which the specimens were measured was selected at random from the three foraminiferal cores taken at each station. It is the author's opinion that these procedures have preserved an unbiased subsample, without requiring the excessive work of measuring every specimen.

As indicated above, specimens of only a few selected species were measured. These species were selected on the basis of their common occurrence on the Oregon Shelf (Boettcher, 1967) and the possession of a growth form which allowed one measurement to give a good indication of test size (Table 14).

In the analysis of specimen size data, it is assumed that the selected foraminiferal species, having a large test size and with numerous chambers in the adult, would undergo reproduction once each year. Most foraminiferans whose life cycles are known undergo reproduction in much shorter intervals (Arnold, 1964, p. 47), but these species are generally small in size and intertidal in habitat. *Elphidium crispum*, a foraminifer slightly larger in size and with more numerous chambers than the ones measured in this study, is known to reproduce once each year in northern latitudes, taking thus two full years to complete the entire cycle of sexual and asexual reproduction (Meyers, 1942, p. 330). A life cycle of this length should be detectable with the present statistical methods and intervals of collection.

Statistical analyses of specimen-size data for each species have yielded uncertain results (Appendix X). For each of the eight species, regression analysis does not show any statistical dependence of

Table 14. Species selected for size measurements and the particular feature of the test measured.

Species	Dimension measured
	Agglutinated species
Eggerella advena	length
Saccammina difflugiformis arenulata	length
	Hyaline species
Brizalina pacifica	length
Globobulimina auriculata	length
Florilus scaphus basispinatus	greater diameter
Nonionella stella	greater diameter
Nonionella turgida digitata	greater diameter
Uvigerina juncea	length

specimen size on ecologic factors. A restricted ecologic factor array was used for this analysis. It consisted of the following parameters and their squares: water depth, temperature, salinity, percent calcium carbonate in the sediment, sediment median grain size, and month of collection. No regression surface accounted for more than about 30% of the variation in size.

The large variation in specimen size found in each sample accounts for the observed lack of significant correlation with environmental parameters. The size range at each time of collection is so great that differences between seasons are not significant; X^2 evaluation of the size-frequency distribution of *Brizalina pacifica* indicated that the differences between seasons is what would be expected from chance alone about 40% of the time (Table 15). The variability of specimen size in one sample is too great to confidently establish trends between samples.

The variability of specimen size within a sample is real. Analysis of variance tests have shown that for *Brizalina pacifica* there is no significant difference in size distribution between the first group of 24 stained specimens measured (the group used as a standard sample) and the next group of 24 stained specimens from the same sample. In addition, both X^2 and analysis of variance have shown that the size-frequency distribution of *Brizalina pacifica* in adjacent cores is not significantly different (Table 16).

Table 15. Size-frequency analysis of <u>Brizalina pacifica</u>, data from all stations.

Size (ocular units)	Frequency				Total
	winter	spring	summer	fall	
0. - 9.	3	3	2	0	8
9. - 10.	1	0	2	2	5
10. - 11.	4	9	1	6	20
11. - 12.	2	8	6	12	28
12. - 13.	5	7	8	3	23
13. - 14.	0	8	6	9	23
14. - 15.	7	9	9	8	33
15. - 16.	5	5	19	12	41
16. - 17.	0	7	10	13	30
17. - 18.	1	6	9	9	25
18. - 19.	0	3	14	10	27
19. - 20.	3	5	12	14	34
20. - 21.	5	4	17	15	41
21. - 22.	0	1	15	12	28
22. - 23.	3	2	4	6	15
23. - 24.	1	3	7	10	21
24. - 25.	0	0	4	2	6
25. - 26.	3	3	3	3	12
26. - 27.	1	0	3	0	4
27. - 28.	0	0	0	0	0
28. - 29.	0	0	1	0	1
29. -	1	1	6	2	10
Total	45	84	158	148	435

$X^2 = 95.9694$

Table 16. Size-frequency analysis of Brizalina pacifica, data from two adjacent cores from station 6910-8.

Size (ocular units)	Core 1	Core 2	Total
0. - 8.	1	0	1
8. - 9.	0	0	0
9. - 10.	0	0	0
10. - 11.	1	1	2
11. - 12.	1	0	1
12. - 13.	0	1	1
13. - 14.	1	2	3
14. - 15.	1	3	4
15. - 16.	3	3	6
16. - 17.	3	2	5
17. - 18.	1	1	2
18. - 19.	1	0	1
19. - 20.	5	2	7
20. - 21.	1	5	6
21. - 22.	2	0	2
22. - 23.	2	0	2
23. - 24.	1	3	4
24. - 25.	0	1	1
Total	24	24	48

In a similar analysis, Resig (1963) considered that the median specimen length of up to 100 specimens of *Eggerella advena* from 34 samples fell into four groups when plotted on depth and grain-size gradients. However, the groups are not very distinct, and an examination of the presented data shows that she also had considerable range in specimen size in any one sample. Her conclusions about size variation of *Eggerella advena* over depth and sediment gradients are considered suspect.

The large variation in specimen size in each sample indicates that these species do not reproduce synchronously once or twice a year. Plots of size-frequency give little or no indication of age classes.

The variations in both frequency distribution and size distribution may have a common source in the biologic components of the environment. If the individuals of only a few species thrive upon settling out from the water column at any one place, then those that thrive can form aggregations or colonies of siblings. Arnold (1953) has found that young individuals tend to disperse from areas of high concentration. He reported that dispersion was strongest when juveniles moved away from the parent test, but that the movement of a single individual was quite random. In the natural environment, there would be multiple, randomly located, centers of dispersion. The microenvironment could be considered to be filled with expanding and interpenetrating "shock waves" of siblings, with many individuals being either front-runners or laggards due to random movement. These "shock waves" could partially merge along a front, yielding a colony with an expanding edge of young, actively moving individuals that are invading a microenvironment new for that colony, and with a stable region of more mature individuals in a microenvironmental area that is fully utilized; movement here would be less (Arnold, 1953). Thus, a foraminiferal colony could resemble the much more familiar rock lichen in the manner in which it progresses across its substrate.

This dispersion could take place in three dimensions. Disturbance of the sediment substrate, either by macro infauna or by bottom currents, could partially cover a colony, yielding a new boundary (in the vertical plane) for the leading edge. The foraminifera themselves may burrow into the sediment in search of food. Thus, a core could sample both leading and trailing edges, yielding in one collection individuals of greatly differing ages and sizes.

CONCLUSIONS

The results of this project are twofold in nature: 1) the conclusions concerning the benthic environment; and 2) the conclusions concerning the benthic foraminifera.

Shelf Benthic Environment

The marine benthic environment of the central Oregon continental shelf is remarkably non-homogeneous. Considerable variation existed in both seasonal and local hydrographic patterns, and in the sedimentary substrate.

At any one season variations in hydrographic characters exist between stations at the same water depth. During the non-upwelling season, the between-station differences in near-bottom water reflect the depth gradient; during upwelling the differences reflect random or local topographic effects. During times of upwelling, a considerable shadow effect can be found in the water shoreward of Heceta and Stonewall banks. The near-bottom water at any one place is sufficiently mixed so that stratification does not exist between 0.6 and 5.0 m above the bottom.

The sedimentary substrate also showed considerable variation between stations at the same depth, but this study has shown little seasonal variation.

The variability of both the sediment and the water between stations and cruises makes it necessary that the environment be measured at each point and time of collection in any study of the Oregon benthic environment or its faunas.

Shelf Benthic Foraminifera

Considerable variation is also found in the foraminiferal faunas. Within-station variation in both species and faunal standing stocks and in percent abundance of dominant species has suggested that foraminiferans are neither uniformly nor randomly distributed, but rather are aggregated or clumped. Considerable variation in specimen size of living individuals in the same sample has been found, but no evidence exists of multimodal distributions resulting from age classes.

The question of the relative importance of the water column versus that of the sedimentary substrate has not been settled. The ecologic measurements made in this study assumed that the bottom-water and substrate did not interact; this assumption has become questionable as a result of the findings of other investigators about lutum transport (Spigai, 1971) and shelf water turbidity (Harlett, 1972). If the near-bottom water is as important in the transportation of fine-grained sediments as their studies have indicated, then the response of foraminiferal faunas and species to the environment will need to be restudied.

Linear multiple regression analyses of faunal parameters from shelf stations showed very little correspondence between variations in the fauna and the seasonal and depth variations in near-bottom hydrography. Only the two parameters, percent living hyaline and percent living agglutinated foraminifers, showed a strong dependence upon sedimentary ecologic factors. Most faunal parameters did not show a strong dependence upon any set of ecologic factors.

Repetition of the regression analyses on the data for each station has indicated that the foraminiferal fauna at each station responded differently to changes in the ecologic environment. At the 75-m station (SG-22) the fauna appeared to be highly dependent upon the variations in food content of the sediment as measured by either the total carbon or organic carbon content. Changes in sediment texture at this station indicated that food content is subject to importation and deportation, along with at least the fine-fraction of the sediment. At other stations, total and hyaline standing stocks depended variously on water phosphate content and median grain size (SG-8), on variations in water depth and sediment percent carbonate at the time of collection (SG-15) and on sediment percent sand (SG-2). Agglutinated standing stock has depended upon water oxygen concentration (SG-15) and on sediment percent calcium carbonate (SG-2). Data from combined stations, SG-8 and SG-6, indicated that total and hyaline standing stocks depended upon water depth and that agglutinated standing stock depended upon median grain size of the sediment.

The species frequency of few samples match that of a lognormal curve; most samples have many more rare species, and fewer dominant species, than would be expected for a lognormal distribution. If random variations in numbers of species result in a lognormal distribution, then the existence of very few dominant species indicates an ecologic control by some feature of the substrate upon the success or failure of a species. Dominant species in a sample are those that settled out of the water onto a favorable substrate that insured reproductive success; non-dominant species are those that did not find the environment conducive to reproduction but could stay alive for at least a short time. It appears that many more foraminiferal species enter a benthic environment than can survive there.

Synecologic analyses also considered the affinities between sampled faunas at the seasonal stations. Most of the samples discussed in this study were found to contain the same fauna. These samples were taken from the outer shelf at depths of 100-200 m. Association analysis of species pairs indicated that the affinity between samples was due to a "natural community" of 15 species that were consistently part of each other's biologic environment. This "natural community" is herein called the Oregon Outer Shelf Fauna.

Upper and lower depth limits to the Oregon Outer Shelf Fauna have not been determined. A different faunal group that might be representative of an Inner Shelf Fauna was found at one station at a depth of 75 m. Another faunal group was found on the upper slope at depths of 450-500 m. However, the number of samples and stations that do not contain the Oregon Outer Shelf Fauna is insufficient to set limits or to designate other faunas at this time.

Fundamental niche approximations and determinations of first order variables for some dominant species showed that most species depended upon a set of first order variables rather than on one limiting factor. Temperature, phosphate concentration and oxygen concentration are common hydrographic first order variables, and percent sand, percent silt, percent clay, organic carbon content and organic nitrogen content are common sedimentary first order variables.

Specimen size of selected species is comparable in adjacent samples, but the range in size in any one sample is too great to show seasonal or other ecologic trends when several samples are compared.

BIBLIOGRAPHY

Agterberg, F. P. 1964. Methods of trend surface analysis. Quarterly of the Colorado School of Mines 59(4, A):111-130.

Anderson, G. J. 1963. Distribution patterns of recent foraminifera of the Bering Sea. Micropaleontology 9(3):305-317.

Arnold, Z. M. 1953. An introduction to the study of movement and dispersal in Allogromia laticollaris Arnold. Contributions of the Cushman Foundation for Foraminiferal Research 4(1):15-21.

______________ 1954. Culture methods in the study of living foraminifera. Journal of Paleontology 28:404-416.

______________ 1964. Biological observations on the foraminifer Spiroloculina hyalina Schulze. University of California Publications in Zoology 72:1-78.

Bandy, O. L. 1953. Ecology and paleoecology of some California foraminifera. Part 1. The frequency distribution of recent foraminifera off California. Journal of Paleontology 27(2):161-182.

______________ 1961. Distribution of Foraminifera, Radiolaria and diatoms in sediments of the Gulf of California. Micropaleontology 7(1):1-26.

______________ 1963a. Larger living Foraminifera of the Continental borderland of southern California. Contributions from the Cushman Foundation for Foraminiferal Research 14(4):121-126.

______________ 1963b. Dominant paralic Foraminifera of southern California and the Gulf of Mexico. Contributions from the Cushman Foundation for Foraminiferal Research 14:127. 134.

Bandy, O. L., J. C. Ingle, Jr. and J. M. Resig. 1964a. Foraminiferal trends, Laguna Beach outfall area, California. Limnology and Oceanography 9(1):112-123.

______________ 1964b. Foraminifera, Los Angeles County outfall area, California. Limnology and Oceanography 9(1):124-137.

Bandy, O. L., J. C. Ingle, Jr. and J. M. Resig. 1964c. Facies trends, San Pedro Bay, California. Geological Society of America Bulletin 75:403-424.

__________ 1965a. Modification of foraminiferal distribution by the Orange County outfall area, California. Transactions of the Marine Technological Society, 1965. p. 54-76.

__________ 1965b. Foraminiferal trends, Hyperion outfall, California. Limnology and Oceanography 10(3):314-332.

Barstow, D., W. Gilbert, K. Park, R. Still and B. Wyatt. 1968. Hydrographic data from Oregon waters, 1966. Data Report 33, Department of Oceanography, Oregon State University, Ref. 68-34. 109 p.

Barstow, D., W. Gilbert and B. Wyatt. 1969a. Hydrographic data from Oregon waters, 1967. Data Report 35, Department of Oceanography, Oregon State University, Ref. 69-3. 77 p.

__________ 1969b. Hydrographic data from Oregon waters, 1968. Data Report 36, Department of Oceanography, Oregon State University, Ref. 69-6. 84 p.

Beerbower, J. R. and D. Jordan. 1969. Application of information theory to paleontologic problems: taxonomic diversity. Journal of Paleontology 31:1184-1198.

Berger, W. H. and F. L. Parker. 1970. Diversity of planktonic Foraminifera in deep-sea sediments. Science 168:1345-1347.

Bertrand, G. A. 1971. A comparative study of the infauna of the central Oregon continental shelf. Ph. D. thesis. Corvallis, Oregon State University. 123 numb. leaves.

Boettcher, R. S. 1967. Foraminiferal trends of the central Oregon shelf. M. S. thesis. Corvallis, Oregon State University. 134 numb. leaves.

Boltovskoy, E. and H. Lena. 1969a. Seasonal occurrences, standing crop and production in benthic Foraminifera of Puerto Deseado. Contributions from the Cushman Foundation for Foraminiferal Research 20:87-95.

Boltovskoy, E. and H. Lena. 1969b. Microdistribution des foraminiferes benthoniques vivants. Revue de Micropaleontologie 12(3):177-185.

Bradshaw, J. S. 1957. Laboratory studies on the rate of growth of the foraminifer, "Streblus beccarii (Linne) var. tepida (Cushman)." Journal of Paleontology 31(6):1138-1147.

__________ 1961. Laboratory experiments on the ecology of Foraminifera. Contributions from the Cushman Foundation for Foraminiferal Research 12(3):87-106.

Brady, H. B. 1888. Note on the reproductive condition of Orbitolites complanata, var. laciniata. Journal of the Royal Microscopical Society, 1888. p. 693-697.

Brooks, A. L. 1967. Standing crop, vertical distribution and morphometrics of Ammonia beccarii (Linne). Limnology and Oceanography 12(4):667-684.

Burma, B. H. 1948. Studies in quantitative paleontology. 1. Some aspects of the theory and practice of quantitative invertebrate paleontology. Journal of Paleontology 22(6):725-761.

__________ 1949. Studies in quantitative paleontology. 2. Multivariate analysis--a new analytical tool for paleontology and geology. Journal of Paleontology 23(1):95-103.

Burt, W. V. and B. Wyatt. 1964. Drift bottle observations of the Davidson Current off Oregon. Studies on Oceanography. p. 156-165.

Buzas, M. A. 1968. On the spatial distribution of Foraminifera. Contributions from the Cushman Foundation for Foraminiferal Research 19(1):1-11.

__________ 1969. Foraminiferal species densities and environmental variables in an estuary. Limnology and Oceanography 14(3):411-422.

Buzas, M. A. and T. G. Gibson. 1969. Species diversity: benthonic Foraminifera in western north Atlantic. Science 163:72-75.

Byrne, J. V. 1962a. Geomorphology of the Continental Terrace off the central coast of Oregon. The Ore Bin 24(5):65-74.

Byrne, J. V. 1962b. Here's a look at offshore Oregon. The Oil and Gas Journal 60:116-119. July 23.

Byrne, J. V. and D. A. Panshin. 1968. Continental Shelf sediments off Oregon. Corvallis, Oregon State University, Cooperative Extension Service, A Sea Grant Publication. 5 unnumb. leaves.

Carey, A. G., Jr. and R. R. Paul. 1968. A modification of the Smith-McIntyre Grab for simultaneous collection of sediment and bottom water. Limnology and Oceanography 13:545-549.

Chamberlin, T. C. 1897. The method of multiple working hypotheses. Journal of Geology 5:837-848.

Cockbain, A. E. 1963. Distribution of Foraminifera in Juan de Fuca and Georgia Straits, British Columbia, Canada. Contributions from the Cushman Foundation for Foraminiferal Research 14(1):35-57.

Cole, L. C. 1949. The measure of interspecific association. Ecology 30:411-424.

Collins, C. A. 1967. Currents on the Oregon Continental Shelf. Transactions of the American Geophysical Union 48(1):130. (Abstract)

Cooper, S. C. 1964. Benthonic Foraminifera of the Chukchi Sea. Contributions from the Cushman Foundation for Foraminiferal Research 15(3):79-104.

Cross, F. A. and L. F. Small. 1967. Copepod indicators of surface water movements off the Oregon Coast. Limnology and Oceanography 12(1):60-72.

Crouch, R. W. 1954. Paleontology and paleoecology of the San Pedro shelf and vicinity. Journal of Paleontology 24(3):182-190.

Culberson, C. and R. M. Pytkowicz. 1970. A near-bottom water sampler. Limnology and Oceanography 15(1):160-162.

Day, D. S. and W. G. Pearcy. 1968. Species associations of benthic fishes on the Continental Shelf and Slope off Oregon. Journal of the Fisheries Research Board of Canada 25(12):2665-2675.

Dryden, A. L. 1931. Accuracy in percentage representation of heavy mineral frequencies. Proceedings of the National Academy of Sciences 17(5):233-238.

Ellis, B. F. and A. R. Messina. 1940-1970. Catalogue of Foraminifera. New York, The American Museum of Natural History, special publication. 72 volumes.

Fager, E. W. 1957. Determination and analysis of recurrent groups. Ecology 38(4):586-595.

__________ 1963. Communities of organisms. In: The Sea, 2, ed. by M. N. Hill. New York, Interscience. p. 415-431.

Fager, E. W. and J. A. McGowan. 1963. Zooplankton species groups in the North Pacific. Science 140(3560):453-460.

Fischer, R. A., A. S. Corbet and C. B. Williams. 1943. The relation between the number of species and the numbers of individuals in a random sample of an animal population. Journal of Animal Ecology 12:42-58.

Flint, J. M. 1899. Recent foraminifera. A descriptive catalogue of specimens dredged by the U.S. Fish Commission steamer Albatross. Report of the U.S. National Museum, 1897. p. 249-350.

Fowler, G. A. and L. D. Kulm. 1966. A multiple corer. Limnology and Oceanography 11(4):630-633.

Garrett, H. E. and R. S. Woodworth. 1958. Statistics in psychology and education. 5th ed. New York, McKay. 448 p.

Gibson, L. B. 1966. Some unifying characteristics of species diversity. Contributions from the Cushman Foundation for Foraminiferal Research 17(4):117-124.

Haman, D. 1969. Seasonal occurrence of Elphidium excavatum (Terquem) in Llandanwg Lagoon (North Wales, U. K.). Contributions from the Cushman Foundation for Foraminiferal Research 20(4):139-142.

Hardy, A. 1965. The open sea: its natural history. Part 1. The world of plankton. Boston, Houghton Mifflin. 335 p.

Harlett, J. C. 1972. Sediment transport on the northern Oregon continental shelf. Ph. D. thesis. Corvallis, Oregon State University. 120 numb. leaves.

Harper, J. L., J. T. Williams and G. R. Sagar. 1965. The behavior of seeds in soil. The heterogeneity of soil surfaces and its role in determining the establishment of plants from seed. Journal of Ecology 51:273-286.

Hooper, K. 1969. A re-evaluation of eastern Mediterranean Foraminifera using factor-vector analysis. Contributions from the Cushman Foundation for Foraminiferal Research 20(4):147-151.

Howarth, R. J. and J. W. Murray. 1969. The Foraminifera of Christchurch Harbor, England: a reappraisal using multivariate techniques. Journal of Paleontology 43:660-675.

Hunger, A. A. 1966. Distribution of foraminifera, Netarts Bay, Oregon. M.S. thesis. Corvallis, Oregon State University. 112 numb. leaves.

Hutchinson, G. E. 1957. Concluding remarks. In: Population studies: animal ecology and demography. Cold Spring Harbor Symposia on Quantitative Biology 22:415-427.

Jacard, P. 1912. The distribution of the flora in the alpine zone. New Phytology 11(1):35-50.

Kaesler, R. L. 1966. Quantitative re-evaluation of ecology and distribution of recent Foraminifera and Ostracoda of Todos Santos Bay, Baja California, Mexico. The University of Kansas Paleontological Contributions, Paper 10. 50 p.

Kormondy, E. J. 1969. Concepts of ecology. Englewood Cliffs, New Jersey, Prentice-Hall. 209 p.

Krumbein, W. C. 1934. The probable error of sampling sediments for mechanical analysis. The American Journal of Science 227:204-214.

__________ 1959. The "sorting out" of geological variables illustrated by regression analysis of factors controlling beach firmness. Journal of Sedimentary Petrology 29(4):575-587.

Krumbein, W. C. and L. L. Sloss. 1958. High speed digital computers in stratigraphic and facies analysis. Bulletin of the American Association of Petroleum Geologists 42(11):2650-2669.

Kulm, L. D. and J. V. Byrne. 1966. Sedimentary response to hydrography in an Oregon estuary. Marine Geology 4:85-118.

Kulm, L. D., D. F. Heinrichs, R. M. Buehrig and D. M. Chambers. 1968. Evidence for possible placer accumulations on the southern Oregon Continental Shelf. The Ore Bin 30(5):81-104.

Lankford, R. R. 1962. Recent Foraminifera from near-shore turbulent zone, western United States and northwest Mexico. Ph. D. thesis. La Jolla, Scripps Institution of Oceanography. 241 numb. leaves.

Le Calvez, J. 1950. Recherches sur les foraminiferes. II. Place de la meiose et sexualite. Archives de Zoologie experimentale et generale 87:211-244.

Lidz, L. 1966. Planktonic Foraminifera in the water column of the mainland shelf off Newport Beach, California. Limnology and Oceanography 11:257-263.

Loeblich, A. R., Jr. and H. Tappan. 1964. Protista. 2. Sarcodina, chiefly "Thecamoebians" and Foraminiferida. In: Treatise on invertebrate paleontology. Part C, ed. by R. C. Moore. Lawrence, Kansas, The Geological Society of America and The University of Kansas Press. 900 p.

Loose, T. L. 1970. Turbulent transport of benthonic Foraminifera. Contributions from the Cushman Foundation for Foraminiferal Research 21(4):164-166.

Lynts, G. W. 1966. Variation of foraminiferal standing crop over short lateral distances in Buttonwood Sound, Florida Bay. Limnology and Oceanography 11(4):562-566.

MacArthur, R. H. 1965. Patterns of species diversity. Biological Review 40:511-533.

McIntire, C. D. 1968. Structural characteristics of benthic algal communities in laboratory streams. Ecology 49(3):520-537.

McIntosh, R. R. 1967. An index of diversity and the relation of certain concepts to diversity. Ecology 48(3):392-404.

McNaughton, S. J. and L. L. Wolf. 1970. Dominance and the niche in ecologic systems. Science 167(3915):131-139.

Manske, D. C. 1968. Distribution of Recent Foraminifera in relation to estuarine hydrography, Yaquina Bay, Oregon. Ph.D. thesis. Corvallis, Oregon State University. 233 numb. leaves.

Margalef, D. F. 1957. La teoria de la informacion en ecologia. Memoriales real Academia de Ciencias i Artes de Barcelona 32(13):373-449.

Merriam, D. F. 1963. Use of trend-surface residuals in interpreting geologic structures. Publications of Stanford University in the Geological Sciences 9(2):686-692.

Meyers, E. H. 1935. The life history of Patellina corrugata Williamson, a foraminifer. Bulletin of the Scripps Institution of Oceanography, Technical Series 3(15):355-392.

__________ 1937. Culture methods for marine foraminifera of the littoral zone. In: Culture methods for invertebrate animals, ed. by Galtsoff et al. Ithaca, New York, Comstock. p. 93-96.

__________ 1942. A quantitative study of the productivity of the Foraminifera in the sea. Proceedings of the American Philosophical Society 85(4):325-342.

__________ 1943. Life activities of Foraminifera in relation to marine ecology. Proceedings of the American Philosophical Society 86:439-458.

Miller, C. B. 1970. Some environmental consequences of vertical migration in marine zooplankton. Limnology and Oceanography 15(5):727-741.

Miller, R. L. 1949. An application of the analysis of variance to paleontology. Journal of Paleontology 23(6):635-640.

__________ 1956. Trend surfaces: their application to analysis and description of environments of sedimentation. 1.

The relation of sediment-size parameters to current-wave systems and physiography. The Journal of Geology 64(5): 425-446.

Murray, J. W. 1965. Significance of benthic foraminiferids in plankton samples. Journal of Paleontology 39:156-157.

Natland, M. L. 1933. The temperature and depth distribution of some Recent and fossil Foraminifera in the southern California region. Bulletin of the Scripps Institution of Oceanography, Technical Series 3:225-330.

Neudeck, R. H. 1968. Editing record of O. S. U. deep-sea camera film. Department of Oceanography, Sediment Lab Files. Corvallis, Oregon State University.

Odum, E. P. 1963. Ecology. New York, Holt, Pinchart and Winston. 152 p.

Odum, E. P. and H. T. Odum. 1959. Fundamentals of ecology. Philadelphia, Saunders. 546 p.

Paine, R. T. 1966. Food web complexity and species diversity. The American Naturalist 100(910):65-75.

Park, K. 1968. Alkalinity and pH off the coast of Oregon. Deep-Sea Research 15:171-183.

Park, K., J. C. Pattullo and B. Wyatt. 1962. Chemical properties as indicators of upwelling along the Oregon coast. Limnology and Oceanography 7(3):435-437.

Parker, F. L. and W. D. Athearn. 1959. Ecology of marsh Foraminifera in Poponesset Bay, Massachusetts. Journal of Paleontology 33:333-343.

Parker, W. K. and T. R. Jones. 1865. On some foraminifera from the North Atlantic and Arctic Oceans, including Davis Straits and Baffin's Bay. Philosophical Transactions of the Royal Society of London 155:325-441.

Pattullo, J. G. and W. V. Burt. 1962. The Pacific Ocean. In: Atlas of the Pacific Northwest. Corvallis, Oregon State University Press. p. 93-95.

Pattullo, J. G. and W. Denner. 1965. Processes affecting seawater characteristics along the Oregon coast. Limnology and Oceanography 10(3):443-450.

Pattullo, J. G. and W. B. McAlister. 1962. Evidence for oceanic frontogenesis off Oregon. Science 135(3498):106-107.

Pearcy, W. G. and C. L. Osterberg. 1967. Depth, diel, seasonal, and geographic variations in Zinc-65 of midwater animals off Oregon. International Journal of Oceanology and Limnology 1(2):103-116.

Peterson, R. G. 1971. Professor, Oregon State University, Department of Statistics. Personal communication.

Phleger, F. B. 1955. Ecology of foraminifera in southeast Mississippi Delta area. Bulletin of the American Association of Petroleum Geologists 39:712-752.

________________ 1960. Ecology and distribution of Recent Foraminifera. Baltimore, Johns Hopkins Press. 297 p.

Phleger, F. B. and R. R. Lankford. 1957. Seasonal occurrences of living benthonic Foraminifera in some Texas bays. Contributions from the Cushman Foundation for Foraminiferal Research 8:93-105.

Pianka, E. R. 1966. Latitudinal gradients in species diversity: a review of concepts. The American Naturalist 100(910):33-46.

Pillsbury, R. 1971. Research Associate, Oregon State University, Department of Oceanography. Personal communication.

Preston, F. W. 1948. The commonness, and rarity, of species. Ecology 29(3):254-283.

________________ 1958. Analysis of the Audubon Christmas counts in terms of the lognormal curve. Ecology 39(4):620-624.

Reiter, M. 1959. Seasonal variations in intertidal Foraminifera in Santa Monica Bay, California. Journal of Paleontology 33:606-630.

Resig, J. M. 1963. Size relationships of *Eggerella advena* to sediment and depth of substratum. In: Recent sediments, Northwestern Gulf of Mexico, ed. by F. P. Shepard, F. B. Phleger and T. H. van Andel. Tulsa, The American Association of Petroleum Geologists. p. 267-301.

Runge, E. J., Jr. 1966. Continental shelf sediments, Columbia River to Cape Blanco, Oregon. Ph.D. thesis. Corvallis, Oregon State University. 143 numb. leaves.

Said, R. 1950. The distribution of Foraminifera in the northern Red Sea. Contributions from the Cushman Foundation for Foraminiferal Research 1(1):9-29.

Sanders, H. L. 1968. Marine benthic diversity: a comparative study. American Naturalist 102(925):243-282.

Shiffett, E. 1961. Living, dead, and total foraminiferal faunas, Heald Bank, Gulf of Mexico. Micropaleontology 7(1):45-54.

Simpson, E. H. 1949. Measurement of diversity. Nature 163:688.

Sliter, W. V. 1965. Laboratory experiments on the life cycle and ecologic controls of Rosalina globularia d'Orbigny. Journal of Protozoology 12(2):210-215.

Smith, R. L. 1966. Upwelling along the Oregon coast. Challenger Society Annual Report 3(17)43.

Smith, R. L., J. G. Pattullo and R. K. Lane. 1966. An investigation of the early stages of upwelling along the Oregon coast. Journal of Geophysical Research 71(4):1135-1140.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical methods. 6th ed. Ames, Iowa. The Iowa State University Press. 593 p.

Sørensen, T. 1948. A method of stabilizing groups of equivalent amplitude in plant sociology based on the similarity of species content and its application to analysis of the vegetation on the Danish commons. Biology Skrift. 5:1-34.

Spigai, J. J. 1971. Marine geology of the Continental Margin off southern Oregon. Ph.D. thesis. Corvallis, Oregon State University. 214 numb. leaves.

Spight, T. M. 1967. Species diversity: a comment on the role of the predator. American Naturalist 101:467-474.

Stehli, F. G. 1965. Paleontologic techniques for defining ancient ocean currents. Science 148(3672)943-946.

Sverdrup, H. U., M. V. Johnson and R. H. Fleming. 1942. The oceans. Englewood Cliffs, Prentice-Hall. 1087 p.

Thomlinson, R. 1971. Research Associate, Oregon State University, Department of Oceanography. Personal communication about results from cruise Y7006A. Corvallis, Oregon.

Todd, R. and D. Low. 1967. Recent Foraminifera from the Gulf of Alaska and southeastern Alaska. Washington, D. C., U.S. Geological Survey Professional Paper 573-A:1-46.

Tully, J. F. 1964. Oceanographic regions and assessment of temperature structure in the seasonal zone of the North Pacific Ocean. Journal of the Fisheries Research Board of Canada 21(5):941-970.

Uchio, T. 1960. Ecology of living benthonic Foraminifera from the San Diego, California, area. Sharon, Massachussets, Contributions from the Cushman Foundation for Foraminiferal Research. 72 p. (Special publication 5)

Vilks, G. 1969. Recent Foraminifera in the Canadian Arctic. Micropaleontology 15(1):35-60.

Walton, W. R. 1952. Techniques for recognition of living Foraminifera. Contributions from the Cushman Foundation for Foraminiferal Research 3:56-60.

__________ 1955. Ecology of living benthonic Foraminifera, Todos Santos Bay, Baja California. Journal of Paleontology 29(6):952-1018.

Weiser, W. 1960. Benthic studies in Buzzards Bay. 2. The meiofauna. Limnology and Oceanography 5:121-137.

Williams, C. B. 1953. The relative abundance of different species in a wild animal population. The Journal of Animal Ecology 22(1):14-31.

__________ 1964. Patterns in the balance of nature. London, Academic. 324 p.

Wyatt, B. and W. E. Gilbert. 1967. Hydrographic data from Oregon waters, 1962 through 1964. Data report 24, Department of Oceanography, Oregon State University, Ref. 67-1. 175 p.

Wyatt, B., W. Gilbert, L. Gordon and D. Barstow. 1970. Hydrographic data from Oregon waters, 1969. Data report 42, Department of Oceanography, Oregon State University, Ref. 70-12. 155 p.

Wyatt, B., R. Still, D. Barstow and W. Gilbert. 1967. Hydrographic data from Oregon waters, 1965. Data report 27, Department of Oceanography, Oregon State University, Ref. 67-28. 56 p.

Yates, T. L. (ed.). 1969. OSU statistical analysis program library. Corvallis, Oregon State University, Department of Statistics. Unnumb. leaves.

APPENDICES

APPENDIX I

FAUNAL REFERENCE LIST

The complete citation for each species recognized in this study is given to aid reference to The Catalog of Foraminifera (Ellis and Messina, 1940-1970). If the name used in this study differs from that of the original designation, both names are given. The name is accompanied by the number of samples in which the species is found (in parentheses) and taxonomic notes as necessary. References to authors of species are not included in the Bibliography unless also cited in the text. The species are listed according to the classification of Loeblich and Tappan (1964).

Agglutinated Foraminiferida

Hippocrepinella alba Heron-Allen and Earland, 1932. (5)

Hippocrepina indivisa Parker, 1870. (3)

Hippocrepina sp. 1. (5) The species might be *Hippocrepina oblonga* = *Hippocrepinella remani* Rhumbler *forma oblonga* Rhumbler, 1935, but too few specimens have been collected to allow positive identification.

Hippocrepina sp. 2. (29) The species might be *H. pusilla* Heron-Allen and Earland, 1930.

Hippocrepina sp. 3. (5) The specimens collected are almost always very thin-walled and collapsed; they were most likely originally spherical with a short neck.

Dendrophyra arborescens (Norman) = *Psammatodendron arborescens* Norman, 1881. (24).

Hyperammina? sp. (1)

Psammosphaera decorata (Earland, 1933) = Proteonina decorata Earland, 1933. (1)

Saccammina bowmanni (Heron-Allen and Earland) = Psammosphaera bowmanni Heron-Allen and Earland, 1912. (16) Also = Saccammina? sp. of Boettcher (1967).

Saccammina bulbosa (Chapman and Parr) = Proteonina bulbosa Chapman and Parr, 1937. (5)

Saccammina comprima (Phleger and Parker) = Proteonina comprima Phleger and Parker, 1951. (3)

Saccammina difflugiformis arenulata (Skinner) = Reophax difflugiformis Brady, arenulata Skinner, 1961. (55) Also = Proteonina atlantica Cushman of several authors, but not = Proteonina atlantica Cushman, 1944. Cushman's P. atlantica is distinguished from S. difflugiformis arenulata by the shape of the test, notably the lack of a definite neck. The subspecies recognized here definitely has the anterior test produced to form a neck, no matter what the size of the specimen nor the size of the component sand grains.

Ammodiscus minutissimus Cushman and McCulloch, 1939. (31) Also = A. hoeglundi Uchio, 1960.

Ammodiscus sp. 1. (1) A fragment of some unidentified large ammodiscid.

Ammodiscus sp. 2. (5) The species might be A. gullmarensis Hoeglund, 1948, but too few specimens have been collected to allow positive identification.

Kalamopsis? sp. (1) Attached to sponge spicules.

Reophax curtus Cushman, 1920. (16)

Reophax dentalinaformis Brady, 1881. (18)

Reophax gracilis (Kiaer) = Nodulina gracilis Kiaer, 1900. (5)

Reophax guttifer (Brady) = Lituola (Reophax) guttifera Brady, 1881. (2)

Reophax horridus? Cushman, 1912. (12) The specimens from this study have fewer sponge spicules than the type illustration.

Reophax micaceous Earland, 1934. (34)

Reophax nanus Rhumbler, 1913. (41)

Reophax scorpiurus Montfort, 1808. (25)

Reophax scotti Chaster, 1890-1891. (1)

Reophax subdentalinaformis Parr, 1950. (31)

Reophax sp. (1)

Nouria polymorphinoides Heron-Allen and Earland, 1914. (43) Includes an unilocular form that may be the juvenile or may be a different species.

Adercotyrma glomerata (Brady) = Lituola glomerata Brady, 1878. (48)

Discammina planissima (Cushman) = Haplophragmoides planissimum Cushman, 1927. (5) Also = Ammotium planissimum of Uchio, 1960.

Recurvoides turbinata (Brady) = Haplophragmoides turbinatum Brady, 1881. (36)

Thalmanammina parkerae (Uchio) = Recurvoides parkerae Uchio, 1960. (67)

Cribrostomoides advena Cushman = Haplophragmoides advena Cushman, 1925. (13)

Cribrostomoides columbiensis (Cushman) = Haplophragmoides columbiensis columbiensis Cushman, 1925. (62)

Cribrostomoides sp. (1) A very flat, thin-walled species.

Spiroplectammina bathica Uchio, 1960. (9)

Spiroplectammina biformis (Parker and Jones) = Textularia agglutinans d'Orbigny, var. biformis Parker and Jones, 1865. (43)

Textularia earlandi Parker, 1952. (46) Also = T. elegans Lacroix, 1932, and T. tenuissima Earland, 1933, but not = T. elegans (Hantken, 1868) nor T. tenuissima Hausler, 1881.

Textularia sandiegoensis Uchio, 1960. (46) The species may be related to T. kattegatensis Hoglund, 1948 (= T. gracillima Hoglund, 1947).

Trochammina charlottensis Cushman, 1925. (16)

Trochammina globigeriniformis Brady, 1881. (2)

Trochammina inflata (Montagu) = Nautilus inflatus Montagu, 1808. (1)

Trochammina ochracea (Williamson) = Rotalina ochracea Williamson, 1858. (3)

Trochammina pacifica Cushman, 1925. (49)

Trochammina sp. 1 (31). A thin-walled and delicate form, often with walls of one or more chambers collapsed.

Trochammina sp. 2 (1)

Gaudryina arenaria Galloway and Wissler, 1927. (28)

Gaudryina subglabrata Cushman and McCulloch, 1939. (4)

Eggerella advena (Cushman) = Verneuilina advena Cushman, 1922. (76)

Eggerella scrippsi Uchio, 1960. (5)

Goesella flintii Cushman, 1936. (10)

Martinottiella cf. M. primaeva (Cushman) = Schenckiella primaeva (Cushman) of Todd and Low (1967), and M. nodulosa Cushman of Boettcher (1967). (2) Not = Clavulina communis d'Orbigny nodulosa Cushman, 1922. Biserial section much shorter than C. primaeva Cushman, 1913, and much like that of C. communis d'Orbigny, var. pallida Cushman, 1927.

Genus C species C. (2)

Porcelaneous Foraminiferida

Cyclogyra incerta (d'Orbigny) = Operculina incerta d'Orbigny, 1839. (1)

Gordiospira sp. (1) Might be G. fragilis Heron-Allen and Earland, 1932.

Quinqueloculina cf. Q. akneriana bellatula Bandy, 1950. (3) Sides of test tend to be more parallel than the type figure.

Quinqueloculina stalkeri Loeblich and Tappan, 1953. (30)

Quinqueloculina sp. 1 = Q. sp. Boettcher (1967). (3)

Quinqueloculina sp. 2. (3)

Quinqueloculina sp. 3. (1)

Sigmoilina cf. S. tenuis (Czjzek, 1848). (4)

Triloculina trigonula (Lamarck) = Miliolites trigonula Lamarck, 1804. (2)

Triloculina cf. T. williamsoni Terquem, 1878. (5) Specimens slightly more elongate with smaller aperture and lacking expanded toothplate than type figure of T. williamsoni, and much more elongate than T. oblonga (Montagu) of Flint (1899). Species = T. oblonga (Montagu) of Boettcher (1967).

Scutoloris sp. (6)

Hyaline Foraminiferida

Dentalina cf. D. baggi Galloway and Wissler, 1927. (2)

Dentalina ittai Loeblich and Tappan, 1953. (2)

Dentalina sp. 1 = D. sp. Boettcher, 1967. (3)

Dentalina sp. 2. (1)

Lenticulina sp. = L. sp. Boettcher, 1967. (3)

Lagena caudata (d'Orbigny) = Oolina caudata d'Orbigny, 1839. (1)

Lagena clavata (d'Orbigny) = Oolina clavata d'Orbigny, 1846. (1)

Lagena costata (Silvestri) = Oolina costata Silvestri, 1894. Not = Oolina costata Egger, 1857. (1)

Lagena dentalinaformis Bagg, 1912. (1)

Lagena distoma Parker and Jones, 1864. (37) Also = L. laevis (Montagu), var. striata (Montagu) of Parker and Jones (1865) and L. gracillima (Seguenza) var. mollis Cushman, 1944.

Lagena elongata (Ehrenberg) = Miliola elongata Ehrenberg, 1844. (1)

Lagena flexa Cushman and Gray, 1946. (1)

Lagena gracilis Williamson, 1848. (2)

Lagena gracillima (Seguenza) = Amphorina gracillima Sequenza, 1862. (8)

Lagena hispida Reuss, 1863. (3)

Lagena laevis (Montagu) = Vermiculum laeve Montagu, 1803. (7)

Lagena melo (d'Orbigny) = Oolina melo d'Orbigny, 1839. (6)

Lagena nebulosa Cushman, 1923 = Lagena laevis nebulosa Cushman, 1923. (18)

Lagena striata (d'Orbigny) = Oolina striata d'Orbigny, 1839. (10)

Lagena striatopunctata Parker and Jones = Lagena sulcata Walker and Jacob striatopunctata Parker and Jones, 1865. (5)

Lagena submagnifica Cushman and Gray, 1946. (2)

Lagena sulcata peculiaris Cushman and McCulloch, 1939. (3)

Lagena sp. 1. (1)

Lagena sp. 2. (16)

Lagena sp. 3. (3)

Lagena sp. 4. (6)

Lagena sp. 5. (3)

Lagena sp. 6. (1)

Lagena sp. 7. (4)

Lagena sp. 8. (4)

Lagena sp. 9. (1)

Lagena sp. 10. (5)

Lagena sp. 11. (1)

Lagena sp. 12. (2)

Marginulina sp. (3)

Polymorphina charlottensis Cushman, 1925. (5)

Polymorphina oregonensis Bandy, 1950. (3)

Sigmomorphina trilocularis (Bagg) = Polymorphina trilocularis Bagg, 1912. (1)

Oolina lineata (Williamson) = Entosolenia lineata Williamson, 1848. (1)

Fissurina marginata (Montagu) = Vermiculum marginatum Montagu, 1803. (21)

Fissurina sp. 1 = F. sp. 1 Boettcher, 1967. (2)

Fissurina? sp. 2 = F. ? sp. 2 Boettcher, 1967. (1)

Buliminella elegantissima (d'Orbigny) = Bulimina elegantissima d'Orbigny, 1839. (20)

Bullimi nella tenuata Cushman = Buliminella subfusiformis tenuata Cushman, 1927. (4)

Bolivina argentia Cushman, 1926. (5)

Bolivina spissa Cushman = *Bolivina subadvena spissa* Cushman, 1926. (6)

Brizalina pacifica (Cushman and McCulloch) = *Bolivina acerosa* Cushman, var. *pacifica* Cushman and McCulloch, 1947. (79)

Islandiella californica (Cushman and Hughes) = *Cassidulina californica* Cushman and Hughes, 1925. (6)

Globobulimina auriculata (Bailey) = *Bulimina auriculata* Bailey, 1851. (50) Also = *Globobulimina* sp. b. Hoglund, 1947.

Globobulimina pacifica Cushman, 1927. (38)

Uvigerina juncea Cushman and Todd, 1941. (70)

Uvigerina peregrina Cushman, 1923. (3)

Trifarina angulosa (Williamson) = *Uvigerina angulosa* Williamson, 1858. (43)

Trifarina baggi (Galloway and Wissler) = *Uvigerina baggi* Galloway and Wissler, 1927. (2)

Buccella frigida (Cushman) = *Pulvinulina frigida* Cushman, 1922. (18)

Epistominella exigua (Brady) = *Pulvinulina exigua* Brady, 1884. (69)

Eilohedra levicula (Resig) = *Epistominella levicula* Resig, 1958. (50) Specimens compared with the holotype (USC Holotype #4407) and paratypes.

Elphidium clavatum (Cushman) = *Elphidium incertum* (Williamson) var. *clavatum* Cushman, 1930, emend. Loeblich and Tappan, 1953. (1)

Cibicides lobatulus (Walker and Jacob) = *Nautilus lobatulus* Walker and Jacob, 1798. (11)

Cibicides lobatulus, *forma omasicus* Cooper, 1965. (3)

Cassidella sp. 1 = *C.* sp. Boettcher, 1967. (26)

Cassidella sp. 2. (8)

Suggrunda eckisi Natland, 1950. (5)

Loxostomum pseudobeyrichi (Cushman) = Bolivina pseudobeyrichi Cushman, 1926. (23) Also = Bolivina alata (Seguenza) of Todd and Low (1967).

Cassidulina delicata Cushman, 1927. (5)

Cassidulina limbata Cushman and Hughes, 1925. (5)

Globocassidulina depressa (Asano and Nakamura) = Cassidulina subglobosa depressa Asano and Nakamura, 1937. (37)

Globocassidulina minuta (Cushman) = Cassidulina minuta Cushman, 1933. (10)

Globocassidulina subglobosa (Brady) = Cassidulina subglobosa Brady 1881. (38)

Chilostomella ovoidea Reuss, 1850. (10)

Astrononion gallowayi Loeblich and Tappan, 1953. (1)

Florilus auriculus (Heron-Allen and Earland) = Nonionella auricula Heron-Allen and Earland, 1930. (43)

Florilus scaphus basispinatus (Cushman and Moyer) = Nonion pizarensis basispinata Cushman and Moyer, 1930. (67)

Nonionella stella Cushman and Moyer = Nonionella miocenica stella Cushman and Moyer, 1930. (68) Also = Nonionella pulchella Hada, 1931 and Nonionella monicana Zalesny, 1959 [specimens compared with the holotype (USC holotype #4570)].

Nonionella turgida digitata Norvang, 1945. (56) Also = Nonionella sp. of Walton (1955), and Nonionella sp. aff. N. globosa Ishiwada of Uchio (1960).

Nonionellina labradorica (Dawson) = Nonionina labradorica Dawson, 1860. (43) Also = Florilus labradoricus (Dawson) of Todd and Low (1967), and Nonionella labradorica (Dawson) of Vilks (1969).

Pullenia salisburyi Stewart and Stewart, 1930. (20)

Gyroidina altiformis Stewart and Stewart = Gyroidina soldanii altiformis Stewart and Stewart, 1930. (6)

Ceratobulimina artica Green, 1960. (7) Also = Alliatina? sp. of Boettcher (1967) and Alliatina primitiva (Cushman and McCulloch) of Uchio (1960); not = Cushmanella primitiva Cushman and McCulloch, 1940.

Geminospira? sp. (4)

Genus A species A. (17)

Genus D species D. (1)

Genus E species E. (1)

APPENDIX II

FORAMINIFERAL SPECIES PERCENT ABUNDANCES

The percent abundance of each species is shown for each station over the seasonal range of collections. The percentage is of the total living benthic foraminiferal fauna; if the summed percentages do not equal 100.00, the missing percentages are represented by unidentified fragments and individuals.

Appendix II-a. Relative abundance of benthic foraminiferal species that occur in more than three samples.

Sample	6901-2.2	6901-2.3	6904-2.1	6904-2.2	6904-2.3	6907-2.1	6907-2.2	6907-2.3	6910-2.1	6910-2.2	6911-2.1	6911-2.2	6911-2.3	6911-2.4	6911-2.5	6911-2.6
AGGLUTINATED SPECIES																
HIPPOCREPINELLA ALBA										1						
HIPPOCREPINA SP. 1																
HIPPOCREPINA SP. 2	8						1	1			1	1	1	3	2	
HIPPOCREPINA SP. 3																
DENDROPHYRA ARBORESCENS			3				1	1				3			3	1
SACCAMMINA BOWMANNI								1								
SACCAMMINA BULBOSA																
SACCAMMINA DIFFLUGIFORMIS ARENULATA			2					1			1	1	1	1	1	
AMMODISCUS MINUTISSIMUS								1		1		1				
AMMODISCUS SP. 2																1
REOPHAX CURTUS					1								1	1		
REOPHAX DENTALINAFORMIS									1			1				
REOPHAX GRACILIS																
REOPHAX HORRIDUS			2		1								1	1	1	
REOPHAX MICACEOUS		7				1			2	1	3	2	2	3	3	1
REOPHAX NANUS																
REOPHAX SCORPIURUS								1	2				1	1	1	1
REOPHAX SUBDENTALINAFORMIS	22				1				1	1		1	4	1		2
NOURIA POLYMORPHINOIDES			5									2		1		1
ADERCOTREMA GLOMERATA			3	2	1		1		2	1	2		1		1	3
DISCAMMINA PLANISSIMUM																
RECURVOIDES TURBINATA											1	1	3		3	
THALMANAMMINA PARKERAE			7	2	1		1	3	1	7	2	3	4	1	4	
CRIBROSTOMOIDES ADVENA																
CRIBROSTOMOIDES COLUMBIENSIS		2	5	2	4	13	5	3	2	2	3	1	2	1		2
SPIROPLECTAMMINA BATHICA																
SPIROPLECTAMMINA BIFORMIS							1			1	1		1			
TEXTULARIA EARLANDI			2		2	1	1		2	1	1	1		2	3	2
TEXTULARIA SANDIEGOENSIS		5			6	5	7	4	7	3	5	1	3	2	6	1
TROCHAMMINA CHARLOTTENSIS									1		1	1		1		
TROCHAMMINA PACIFICA			2			1			1	2	3	3	1	2	1	
TROCHAMMINA SP. (THIN WALLED)					1	1		1		1	1					
GAUDRYINA ARENARIA																
EGGERELLA ADVENA	3		2	4	5	2	2		6	3	4	9	4	4	3	2
EGGERELLA SCRIPPSI																
GOESELLA FLINTII																
PORCELANEOUS SPECIES																
QUINQUELOCULINA STALKERI						1	x		6	2		5	1	10	5	3
SIGMOILINA cf. S. TENUIUS								1			1					1
TRILOCULINA cf. T. WILLIAMSONI															1	
SCUTOLORIS SP.												1				
HYALINE SPECIES																
LAGENA DISTOMA												2	2			1
LAGENA GRACILLIMA													1			
LAGENA LAEVIS																
LAGENA MELO																
LAGENA NEBULOSA												1	2			
LAGENA STRIATA				2												
LAGENA STRIATOPUNCTATA									1						1	
LAGENA SP. 1																
LAGENA SP. 2					1							1	1	1		
LAGENA SP. 4												1				
LAGENA SP. 7																
LAGENA SP. 8													1			
LAGENA SP. 10																
POLYMORPHINA CHARLOTTENSIS																
FISSURINA MARGINATA				2									1	1		
BULIMINELLA ELEGANTISSIMA													1			
BULIMINELLA TENUATA																
BOLIVINA ARGENTIA																
BOLIVINA SPISSA																
BRIZALINA PACIFICA	56	63	22	31	50	55	52	46	35	43	43	36	23	37	38	51
ISLANDIELLA CALIFORNICA																1
GLOBOBULIMINA AURICULATA		17	2	2		1	2	2			1	1	3	2	1	2
GLOBOBULIMINA PACIFICA					1				2		3	1	3	1	2	1
UVIGERINA JUNCEA	6	2	8	15	14	2	4	8	6	6	2	7	16	4	4	5
TRIFARINA ANGULOSA			2	2		1	x					1	1			1
BUCCELLA FRIGIDA																
EPISTOMINELLA EXIGUA			25	24	7	2	3	6	13	11	8	9	7	2	8	10
EILOHEDRA LEVICULA	3					1	x	2	2	2	3	2	1	2	1	3
CIBICIDES LOBATULUS					1											
CIBICIDES LOBATULUS forma OMASICUS																
CASSIDELLA SP. 1				2		1										
CASSIDELLA SP. 2																
SUGGRUNDA ECKISI																
LOXOSTOMUM PSEUDOBEYRICHI			3				x			1	3		3	3		
CASSIDULINA DELICATA							x									
CASSIDULINA LIMBATA																
GLOBOCASSIDULINA DEPRESSA						1	x	3	1	3	2	1	1	1		2
GLOBOCASSIDULINA MINUTA						1	x	2					1		1	
GLOBOCASSIDULINA SUBGLOBOSA						1		1	1	1			1	3	1	
CHILOSTOMELLA OVOIDEA				2			3	1			1					
FLORILUS AURICULUS						1	x			1			1			1
FLORILUS SCAPHUS BASISPINATUS			3			5	7	4	3	2		1	2	2		1
NONIONELLA TURGIDA DIGITATA		2	2		1	3	3	3	1	2	2		1	1	2	
NONIONELLA STELLA	3					1	2	3	2	2	3	2		1	3	1
NONIONELLINA LABRADORICA				5					1			1				1
PULLENIA SALISBURYI								1	1	1				1	1	1
GYROIDINA ALTIFORMIS																
GERATOBULIMINA ARCTICA																1
GEMINOSPIRA SP.												1		1		
GENUS A SPECIES A							x		2		1					

Sample	6904-6.2	6907-6.1	6907-6.2	6907-6.3	6911-6.1	6911-6.3	6911-6.4	6904-7.1	6904-7.2	6904-7.3	6907-7.2	6907-7.3	6911-7.1	6911-7.2	6911-7.3
AGGLUTINATED SPECIES															
HIPPOCREPINELLA ALBA										1					
HIPPOCREPINA SP. 1	x											1			
HIPPOCREPINA SP. 2	1										1				
HIPPOCREPINA SP. 3															
DENDROPHYRA ARBORESCENS			3	1									x	1	
SACCAMMINA BOWMANNI				1								1	x	1	2
SACCAMMINA BULBOSA											1			1	1
SACCAMMINA DIFFLUGIFORMIS ARENULATA	1	1	6		2	5	2			2	2	2	3	1	1
AMMODISCUS MINUTISSIMUS	1	x													
AMMODISCUS SP. 2															
REOPHAX CURTUS	x						1					1			
REOPHAX DENTALINAFORMIS	x				1			2	1	1				1	1
REOPHAX GRACILIS												x			
REOPHAX HORRIDUS		x								1			x		
REOPHAX MICACEOUS	x	1	1	1	1	1	2	2		2				1	
REOPHAX NANUS		1		2	1	1	1	2	6	1		1	1	1	1
REOPHAX SCORPIURUS		x	2		2		2			1		1	x	1	
REOPHAX SUBDENTALINAFORMIS		2		2	1	7	3					x			
NOURIA POLYMORPHINOIDES	4	7	7	7	6	3	6			2		1	1	1	
ADERCOTREMA GLOMERATA	1	1		1	1								x		
DISCAMMINA PLANISSIMUM															
RECURVOIDES TURBINATA	x			1			1		1			1	x		
THALMANAMMINA PARKERAE	3	2	4	8	5	3	5	3	4	2	7	1	1	8	1
CRIBROSTOMOIDES ADVENA															
CRIBROSTOMOIDES COLUMBIENSIS	1	1	1	8	3	3		2	1			x	x	1	
SPIROPLECTAMMINA BATHICA															
SPIROPLECTAMMINA BIFORMIS	1	x			1		1		1		1	1	3	2	1
TEXTULARIA EARLANDI	1	1	3	3		4	1				1		2	1	
TEXTULARIA SANDIEGOENSIS	1	x	2		1		3					x			
TROCHAMMINA CHARLOTTENSIS													x		
TROCHAMMINA PACIFICA	x	1					2						x		1
TROCHAMMINA SP. (THIN WALLED)	1			3	2	1	1					1	3	1	
GAUDRYINA ARENARIA															
EGGERELLA ADVENA	18	16	7	13	13	9	4		3	1	3	x	2	1	1
EGGERELLA SCRIPPSI										1					
GOESELLA FLINTII															
PORCELANEOUS SPECIES															
QUINQUELOCULINA STALKERI		x	1		1				1				2	1	
SIGMOILINA cf. S. TENUIUS															
TRILOCULINA cf. T. WILLIAMSONI												1			
SCUTOLORIS SP.	x												1		
HYALINE SPECIES															
LAGENA DISTOMA		2			2	3	1		6	1		1	1	1	2
LAGENA GRACILLIMA						1									
LAGENA LAEVIS		x			1										
LAGENA MELO									1						
LAGENA NEBULOSA		1			1			2			2	x			1
LAGENA STRIATA		x													
LAGENA STRIATOPUNCTATA															
LAGENA SP. 1															
LAGENA SP. 2									1	1			x	1	1
LAGENA SP. 4		1									1				
LAGENA SP. 7															
LAGENA SP. 8									1						
LAGENA SP. 10	1												x		
POLYMORPHINA CHARLOTTENSIS															
FISSURINA MARGINATA		x	1		1								1	1	1
BULIMINELLA ELEGANTISSIMA								2	1		1	1	x		
BULIMINELLA TENUATA															
BOLIVINA ARGENTIA															
BOLIVINA SPISSA															
BRIZALINA PACIFICA	4	14	16	10	17	15	15	13	6	2	20	13	5	11	1
ISLANDIELLA CALIFORNICA															
GLOBOBULIMINA AURICULATA	x	1	3				2	8	4	7	2	8	8	2	18
GLOBOBULIMINA PACIFICA	x	4	1	1	1		6	10	8	5	3	6	4	2	1
UVIGERINA JUNCEA	5	13	7	19	10	1	5	2	6	2	7	4	7	6	9
TRIFARINA ANGULOSA		x										x			
BUCCELLA FRIGIDA								2		1	1			x	1
EPISTOMINELLA EXIGUA	19	13	7	11	12	8	9			1	1		2	2	
EILOHEDRA LEVICULA	3	2	1	2	3	3									
CIBICIDES LOBATULUS	1														
CIBICIDES LOBATULUS forma OMASICUS															
CASSIDELLA SP. 1	x			1							1	x	1	1	
CASSIDELLA SP. 2					1	1									
SUGGRUNDA ECKISI															
LOXOSTOMUM PSEUDOBEYRICHI		x													
CASSIDULINA DELICATA															
CASSIDULINA LIMBATA															
GLOBOCASSIDULINA DEPRESSA															
GLOBOCASSIDULINA MINUTA															
GLOBOCASSIDULINA SUBGLOBOSA	18	1	2		3		3		1	1		x	2	2	
CHILOSTOMELLA OVOIDEA															
FLORILUS AURICULUS	1						1						1	x	
FLORILUS SCAPHUS BASISPINATUS	1	3	2	1	1	1	6	26	18	33	30	19	13	11	14
NONIONELLA TURGIDA DIGITATA	3	2	14		3	16	10	10	10	9	2	9	4	2	10
NONIONELLA STELLA	3	1	8	3	2	4	4	6	7	1	5	6	9	21	13
NONIONELLINA LABRADORICA	4	x	4	2	6	7	6	11	8	16	9	15	19	16	16
PULLENIA SALISBURYI				1											
GYROIDINA ALTIFORMIS															
GERATOBULIMINA ARCTICA															
GEMINOSPIRA SP.															
GENUS A SPECIES A		1			1		1					x		x	

Sample	6901-8.4	6901-8.5	6901-8.6	6904-8.1	6904-8.2	6904-8.3	6907-8.2	6910-8.1	6910-8.2	6910-8.3	6911-8.1	6911-8.2	6911-8.3	6911-9.1	6911-9.2	6911-9.3
AGGLUTINATED SPECIES																
HIPPOCREPINELLA ALBA		1					1						1			
HIPPOCREPINA SP. 1																
HIPPOCREPINA SP. 2	x														x	x
HIPPOCREPINA SP. 3											2					x
DENDROPHYRA ARBORESCENS	x	x				1					x		1	x		
SACCAMMINA BOWMANNI											x		x		x	
SACCAMMINA BULBOSA									1							
SACCAMMINA DIFFLUGIFORMIS ARENULATA		x		1	1		x					1	1		x	1
AMMODISCUS MINUTISSIMUS	x						x							x	x	1
AMMODISCUS SP. 2																
REOPHAX CURTUS							x							1		x
REOPHAX DENTALINAFORMIS															2	
REOPHAX GRACILIS									1		x					
REOPHAX HORRIDUS	x												x			x
REOPHAX MICACEOUS	1	1	1			3	1		1	1			1			x
REOPHAX NANUS		x					x	1		1	x			1	x	
REOPHAX SCORPIURUS						1	x	1			x					
REOPHAX SUBDENTALINAFORMIS	x		1				x			1	1	2		6		2
NOURIA POLYMORPHINOIDES	x	x	3	2	11	8	3	1	8	1	2	4	x	x	1	2
ADERCOTREMA GLOMERATA		x		1	1	1	1			1			1	2	2	1
DISCAMMINA PLANISSIMUM											x					
RECURVOIDES TURBINATA		x			1			2	1		1			1	x	
THALMANAMMINA PARKERAE	1	1	3	2		3	2	1	2	3	3	1	3	10	12	6
CRIBROSTOMOIDES ADVENA																
CRIBROSTOMOIDES COLUMBIENSIS	3		2	1		3	1		1	1	2	4	2	3	x	2
SPIROPLECTAMMINA BATHICA																
SPIROPLECTAMMINA BIFORMIS	1	x					1			1	1	x	x	x	x	
TEXTULARIA EARLANDI		3	3	2	3	3	1	4		4	2	x	1	2	7	3
TEXTULARIA SANDIEGOENSIS	2		3	1	4	5	x	5	2	3	3	1	1	x	x	
TROCHAMMINA CHARLOTTENSIS										2				x		
TROCHAMMINA PACIFICA		1	1		2	1	x				x			3	1	1
TROCHAMMINA SP. (THIN WALLED)	x		1	2		2	1	1	2		3	4	1			x
GAUDRYINA ARENARIA											x					x
EGGERELLA ADVENA	1	4	3	7	5	11	11	10	5	11	2	2	3	10	6	2
EGGERELLA SCRIPPSI	x						x						x			
GOESELLA FLINTII				1								x				
PORCELANEOUS SPECIES																
QUINQUELOCULINA STALKERI							1		1	1	1	5	1	x	4	2
SIGMOILINA cf. S. TENUIUS		x														
TRILOCULINA cf. T. WILLIAMSONI						1										
SCUTOLORIS SP.				1								x				
HYALINE SPECIES																
LAGENA DISTOMA		x			2		1			1	1		x	1	x	1
LAGENA GRACILLIMA						1										1
LAGENA LAEVIS							x									
LAGENA MELO															x	
LAGENA NEBULOSA		x						1	1		x		x		x	
LAGENA STRIATA														x		
LAGENA STRIATOPUNCTATA																
LAGENA SP. 1																
LAGENA SP. 2											x			x	x	
LAGENA SP. 4																x
LAGENA SP. 7	x	x											x	1		
LAGENA SP. 8																
LAGENA SP. 10															x	x
POLYMORPHINA CHARLOTTENSIS																
FISSURINA MARGINATA	x		x							1	x	x			x	
BULIMINELLA ELEGANTISSIMA	1	x						1							x	
BULIMINELLA TENUATA																
BOLIVINA ARGENTIA																
BOLIVINA SPISSA																
BRIZALINA PACIFICA	32	5	20	40	21	22	28	32	32	21	38	30	39	16	14	15
ISLANDIELLA CALIFORNICA																
GLOBOBULIMINA AURICULATA	1		1				3				x	1	1	2	5	4
GLOBOBULIMINA PACIFICA			1		2	1					x	1	1	2	2	5
UVIGERINA JUNCEA	13	4	10	6	15	7	7	2	7	9	7	18	10	9	11	10
TRIFARINA ANGULOSA	x	x					x		1			x		2	1	x
BUCCELLA FRIGIDA	1						x									
EPISTOMINELLA EXIGUA	18	61	18	14	15	11	16	21	16	18	6	6	8	8	9	4
EILOHEDRA LEVICULA	6	2	1	4	4	2	5	2	2	8	1	2	1	2	2	2
CIBICIDES LOBATULUS																
CIBICIDES LOBATULUS forma OMASICUS																
CASSIDELLA SP. 1	2	2	3				1	1	1	1	1		1	x	x	1
CASSIDELLA SP. 2		x	1					1	1			x	x			
SUGGRUNDA ECKISI		x	1							1		x	x			
LOXOSTOMUM PSEUDOBEYRICHI	1		1	1			x	1	1	1		1	x			
CASSIDULINA DELICATA																
CASSIDULINA LIMBATA																
GLOBOCASSIDULINA DEPRESSA		x													x	
GLOBOCASSIDULINA MINUTA																
GLOBOCASSIDULINA SUBGLOBOSA		1					4	1	1	2	1	2	1	2	x	x
CHILOSTOMELLA OVOIDEA									1							
FLORILUS AURICULUS	2	x		2				1		1	1		x			
FLORILUS SCAPHUS BASISPINATUS	2	1	6	5	2	6	3	2	1	2	3	3	3	3	3	11
NONIONELLA TURGIDA DIGITATA	4	1		2		2	1	2	3	1	3	2	4	x	2	3
NONIONELLA STELLA	2	4	11	8	4	1	3	2	2	2	7	3	8	5	5	13
NONIONELLINA LABRADORICA		x	5		3			2	4	1	3	1	4	2	1	1
PULLENIA SALISBURYI		x	1		1						1			1	x	1
GYROIDINA ALTIFORMIS																
GERATOBULIMINA ARCTICA									1		1	1		x		x
GEMINOSPIRA SP.																
GENUS A SPECIES A		1	1				x	1				x	x			

	6904-10.1	6904-10.2	6904-10.3	6907-10.2	6907-10.3	6911-10.1	6911-10.2	6911-10.3	6810-15-1.1	6904-15.1	6904-15.2	6904-15.3	6907-15.1	6907-15.5	6910-15.2	6910-15.3	6911-15.1	6911-15.2
AGGLUTINATED SPECIES																		
HIPPOCREPINELLA ALBA																		
HIPPOCREPINA SP. 1													4		1	2		
HIPPOCREPINA SP. 2							3	3		2	2	6			4	3	2	
HIPPOCREPINA SP. 3																		
DENDROPHYRA ARBORESCENS						2	1						1	1	1	6		
SACCAMMINA BOWMANNI	2													x	3	3	2	
SACCAMMINA BULBOSA																		
SACCAMMINA DIFFLUGIFORMIS ARENULATA	4	12	5		7		3	2			2		2	x	4	4		
AMMODISCUS MINUTISSIMUS					13		3	1			2	3		x	1		1	1
AMMODISCUS SP. 2								1								1		
REOPHAX CURTUS											2			1	1	1		
REOPHAX DENTALINAFORMIS		2					6			2			2	2	1	4	1	
REOPHAX GRACILIS																		
REOPHAX HORRIDUS?		2																
REOPHAX MICACEOUS	4		3				6	2						x	1			
REOPHAX NANUS									14		3		4	1	3	1		3
REOPHAX SCORPIURUS						3	1			2	2			x	2			
REOPHAX SUBDENTALINAFORMIS	7		3			18	6	19						1			1	
NOURIA POLYMORPHINOIDES			2							2	3	3	2	1	1	3		3
ADERCOTREMA GLOMERATA	2	2	2			5		1		10			1	1	2			4
DISCAMMINA PLANISSIMUM				6	7	2		1										
RECURVOIDES TURBINATA										5	6	6	2	3	2	2	8	7
THALMANAMMINA PARKERAE			2			2	1	2	3	2	5	3	2	3	16	8	2	7
CRIBROSTOMOIDES ADVENA	7					3	1			2						1	1	
CRIBROSTOMOIDES COLUMBIENSIS									1	12	5	6	3	3	1	2	1	
SPIROPLECTAMMINA BATHICA	7	2	6	6	7	3	1	2										
SPIROPLECTAMMINA BIFORMIS								1	3	10	5		6	1	6	4	4	
TEXTULARIA EARLANDI									28					x				
TEXTULARIA SANDIEGOENSIS				6									3	x	1	1		
TROCHAMMINA CHARLOTTENSIS				6														
TROCHAMMINA PACIFICA		2	2	6	20		1			2	2		2	1	1		2	8
TROCHAMMINA SP.1 (THIN WALLED)											2				1			
GAUDRYINA ARENARIA									3	5	6	6	3	3	3	1	11	21
EGGERELLA ADVENA			2	18	7			1				6	8	2	8	2	4	
EGGERELLA SCRIPPSI					7													
GOESELLA GLINTII	20	12	3	12	7	11	9	6										
PORCELANEOUS SPECIES																		
QUINQUELOCULINA STALKERI						2	1	1										
SIGMOILINA cf. S. TENIUIS																		
TRILOCULINA cf. T. WILLIAMSONI								1						x				
SCUTOLORIS SP.																	1	
HYALINE SPECIES																		
LAGENA DISTOMA				6								3	1	x				
LAGENA GRACILLIMA																		1
LAGENA LAEVIS																		
LAGENA MELO																		
LAGENA NEBULOSA														x				
LAGENA STRIATA																	1	1
LAGENA STRIATOPUNCTATA																		
LAGENA SP. 1																		
LAGENA SP. 2																		1
LAGENA SP. 4																		3
LAGENA SP. 7																		
LAGENA SP. 8												3						
LAGENA SP. 10															2			
POLYMORPHINA CHARLOTTENSIS															1			
FISSURINA MARGINATA																		
BULIMENELLA ELEGANTISSIMA															1			1
BULIMINELLA TENUATA	7	10	11					1										
BOLIVINA ARGENTIA		10	8			3	1	2										
BOLIVINA SPISSA	15	5	11	6			1	2										
BRIZALINA PACIFICA	7	2	2	6		3	1	2	17		13	10	18	25	6	14	8	
ISLANDIELLA CALIFORNICA																		
GLOBOBULIMINA AURICULATA											2		1	3	1		3	1
GLOBOBULIMINA PACIFICA														1			1	
UVIGERINA JUNCEA	2	5	3				1	2		2	3	3	4	5	9	9	10	
TRIFARINA ANGULOSA	2	7	2	18	20	2	7	1			2		2		1	1	1	1
BUCCELLA FRIGIDA										5		6	5		3	5	3	4
EPISTOMINELLA EXIGUA		2	2			3	1	1	3	7	2	6	2	x	3	1	2	3
EILOHEDRA LEVICULA			2					1					2	1				
CIBICIDES LOBATULUS																		
CIBICIDES LOBATULUS forma OMASICUS																		
CASSIDELLA SP. 1								1										
CASSIDELLA SP. 2																		
SUGGRUNDA ECKISI																		
LOXOSTOMUM PSEUDOBEYRICHI	9	7	15			16	14	6										
CASSIDULINA DELICATA									1									
CASSIDULINA LIMBATA											2							
GLOBOCASSIDULINA DEPRESSA									1					1		1		3
GLOBOCASSIDULINA MINUTA			2						1									
GLOBOCASSIDULINA SUBGLOBOSA														3	1		1	1
CHILOSTOMELLA OVOIDEA		2				3	1	7										
FLORILUS AURICULUS						3	4	11					1	2		1		3
FLORILUS SCAPHUS BASISPINATUS			2			3	10	10	6	20	33	23	10	7	11	17	11	
NONIONELLA TURGIDA DIGITATA	2					2	1						2	4	1	3	6	4
NONIONELLA STELLA			2			2			18	7	2	3	6	15	2	1	16	4
NONIONELLINA LABRADORICA							1		1				2	4	2	1		4
PULLENIA SALISBURYI																		
GYROIDINA ALTIFORMIS	2	5	9			8	4	6										
GERATOBULIMINA ARCTICA																		
GEMINOSPIRA SP.							1											
GENUS A SPECIES A	2																	

	6808-22-3.1	6810-22.2	6901-22.1	6901-22.2	6901-22.3	6907-22.1	6907-22.2	6907-22.3	6911-22.1	6911-22.2	6911-22.3	6911-25.1	6911-25.2	6911-25.3
AGGLUTINATED SPECIES														
HIPPOCREPINELLA ALBA														
HIPPOCREPINA SP. 1														
HIPPOCREPINA SP. 2			3		2		2	2						
HIPPOCREPINA SP. 3												1	x	
DENDROPHYRA ARBORESCENS														
SACCAMMINA BOWMANNI												1		
SACCAMMINA BULBOSA														
SACCAMMINA DIFFLUGIFORMIS ARENULATA	41	53	27	50	73	17	22	30	25	37	43	1	1	
AMMODISCUS MINUTISSIMUS		3		10	2		5		1					
AMMODISCUS SP. 2														
REOPHAX CURTUS													x	
REOPHAX DENTALINAFORMIS														
REOPHAX GRACILIS										2				1
REOPHAX HORRIDUS?														
REOPHAX MICACEOUS													1	
REOPHAX NANUS	18	5	3	10		4	5	2	10		2	4	1	3
REOPHAX SCORPIURUS														
REOPHAX SUBDENTALINAFORMIS													1	
NOURIA POLYMORPHINOIDES													x	
ADERCOTREMA GLOMERATA			33		2							x	x	
DISCAMMINA PLANISSIMUM														
RECURVOIDES TURBINATA												2	x	x
THALMANAMMINA PARKERAE												8	5	4
CRIBROSTOMOIDES ADVENA														
CRIBROSTOMOIDES COLUMBIENSIS									1	2		x	1	1
SPIROPLECTAMMINA BATHICA							3							
SPIROPLECTAMMINA BIFORMIS			3			2						2	1	1
TEXTULARIA EARLANDI									1			4	1	1
TEXTULARIA SANDIEGOENSIS												1	1	
TROCHAMMINA CHARLOTTENSIS													x	
TROCHAMMINA PACIFICA						2						x	x	
TROCHAMMINA SP.1 (THIN WALLED)						2					2	x	x	
GAUDRYINA ARENARIA	6		6			2	3	2	1					
EGGERELLA ADVENA	29	18	15	20	5	37	22	47	23	20	15	3	4	4
EGGERELLA SCRIPPSI														
GOESELLA GLINTII														
PORCELANEOUS SPECIES														
QUINQUELOCULINA STALKERI												x	1	1
SIGMOILINA cf. S. TENIUIS														
TRILOCULINA cf. T. WILLIAMSONI														
SCUTOLORIS SP.														
HYALINE SPECIES														
LAGENA DISTOMA												2	x	1
LAGENA GRACILLIMA												2	1	1
LAGENA LAEVIS												1		
LAGENA MELO														1
LAGENA NEBULOSA												x	1	1
LAGENA STRIATA												1	x	
LAGENA STRIATOPUNCTATA		3							1					
LAGENA SP. 1														
LAGENA SP. 2														
LAGENA SP. 4														
LAGENA SP. 7														
LAGENA SP. 8												1		
LAGENA SP. 10														
POLYMORPHINA CHARLOTTENSIS		3							1		2			
FISSURINA MARGINATA												x		
BULIMENELLA ELEGANTISSIMA		3	3		2	7		3	15	7	4			
BULIMINELLA TENUATA														
BOLIVINA ARGENTIA														
BOLIVINA SPISSA														
BRIZALINA PACIFICA							3		4	2		14	25	23
ISLANDIELLA CALIFORNICA														
GLOBOBULIMINA AURICULATA					2		11					6	4	7
GLOBOBULIMINA PACIFICA												5	2	5
UVIGERINA JUNCEA												4	7	6
TRIFARINA ANGULOSA													x	
BUCCELLA FRIGIDA						2			1					
EPISTOMINELLA EXIGUA						2	3					8	2	9
EILOHEDRA LEVICULA												1	2	1
CIBICIDES LOBATULUS								2						
CIBICIDES LOBATULUS forma OMASICUS														
CASSIDELLA SP. 1									2			2	1	2
CASSIDELLA SP. 2														
SUGGRUNDA ECKISI														
LOXOSTOMUM PSEUDOBEYRICHI												x		
CASSIDULINA DELICATA									1		4			
CASSIDULINA LIMBATA														
GLOBOCASSIDULINA DEPRESSA	6	11	6	10	7	9	22	2	1	6	11			
GLOBOCASSIDULINA MINUTA														
GLOBOCASSIDULINA SUBGLOBOSA												2	1	1
CHILOSTOMELLA OVOIDEA														
FLORILUS AURICULUS					2	9		7	7	9	7	1	2	1
FLORILUS SCAPHUS BASISPINATUS									1	6	2	4	8	6
NONIONELLA TURGIDA DIGITATA												6	8	11
NONIONELLA STELLA		3				4			2	6	7	5	5	4
NONIONELLINA LABRADORICA												4	9	7
PULLENIA SALISBURYI													1	
GYROIDINA ALTIFORMIS														
GERATOBULIMINA ARCTICA														
GEMINOSPIRA SP.								2						
GENUS A SPECIES A												x		

	6808-26-1.1	6808-26-1.2	6808-26-1.3	6904-26.1	6904-26.2	6904-26.3	6907-26.1	6907-26.2	6907-26.3	6911-26.1	6911-26.2	6911-26.3
AGGLUTINATED SPECIES												
HIPPOCREPINELLA ALBA												
HIPPOCREPINA SP. 1												
HIPPOCREPINA SP. 2		2	5	1		2						
HIPPOCREPINA SP. 3												
DENDROPHYRA ARBORESCENS						1			1			
SACCAMMINA BOWMANNI						1						
SACCAMMINA BULBOSA												
SACCAMMINA DIFFLUGIFORMIS ARENULATA					1	1				2		3
AMMODISCUS MINUTISSIMUS				2	1	1	8	2	2			6
AMMODISCUS SP. 2						1					5	
REOPHAX CURTUS			1									6
REOPHAX DENTALINAFORMIS												
REOPHAX GRACILIS												
REOPHAX HORRIDUS?												
REOPHAX MICACEOUS	1					x						
REOPHAX NANUS				1				1	1			
REOPHAX SCORPIURUS				1								
REOPHAX SUBDENTALINAFORMIS			1									
NOURIA POLYMORPHINOIDES		1						1				
ADERCOTREMA GLOMERATA		1	1	1			3	8	1	2	23	10
DISCAMMINA PLANISSIMUM												
RECURVOIDES TURBINATA				1		1	12	6		9	3	3
THALMANAMMINA PARKERAE		1		1		2	2	1	1		3	3
CRIBROSTOMOIDES ADVENA	2	1		1	1	1		3	5			
CRIBROSTOMOIDES COLUMBIENSIS	2	3	3	5		15		1	6	2		3
SPIROPLECTAMMINA BATHICA												
SPIROPLECTAMMINA BIFORMIS			1			1	2	1	3	2		
TEXTULARIA EARLANDI	1			1		1	3	2	1			
TEXTULARIA SANDIEGOENSIS			2	2		x	5	1	1			
TROCHAMMINA CHARLOTTENSIS		1		2	4	2	5	3	1			
TROCHAMMINA PACIFICA	4	3		3	5	1	12	1	9	2	10	3
TROCHAMMINA SP.1 (THIN WALLED)		1										
GAUDRYINA ARENARIA		8		3	7	3	3	8	6	33	15	26
EGGERELLA ADVENA	1	1		1		1		11	14	2		3
EGGERELLA SCRIPPSI												
GOESELLA GLINTII												
PORCELANEOUS SPECIES												
QUINQUELOCULINA STALKERI												
SIGMOILINA cf. S. TENIUIS												
TRILOCULINA cf. T. WILLIAMSONI												
SCUTOLORIS SP.												
HYALINE SPECIES												
LAGENA DISTOMA		1	1	1	1	x	3		1			
LAGENA GRACILLIMA												
LAGENA LAEVIS					1	x			1			
LAGENA MELO					3	x						
LAGENA NEBULOSA												
LAGENA STRIATA			1	1		x						
LAGENA STRIATOPUNCTATA									1			
LAGENA SP. 1							2					
LAGENA SP. 2					1		2		1			
LAGENA SP. 4						x						
LAGENA SP. 7												
LAGENA SP. 8												
LAGENA SP. 10												
POLYMORPHINA CHARLOTTENSIS					1							
FISSURINA MARGINATA			1	1	5	2						
BULIMENELLA ELEGANTISSIMA												
BULIMINELLA TENUATA												
BOLIVINA ARGENTIA												
BOLIVINA SPISSA												
BRIZALINA PACIFICA	55	39	45	44	28	30		21	18	2	13	6
ISLANDIELLA CALIFORNICA	1		1	4	2	1						
GLOBOBULIMINA AURICULATA	6	1	2	1		x						3
GLOBOBULIMINA PACIFICA			1			1						
UVIGERINA JUNCEA		6	1	2	1	2		4	5			
TRIFARINA ANGULOSA			1	1	1	1	5	6	8	5	5	10
BUCCELLA FRIGIDA				1		x						
EPISTOMINELLA EXIGUA	4	2	1	2		1	15	4	5		3	
EILOHEDRA LEVICULA		2		1	3	x	2	3	3	5		3
CIBICIDES LOBATULUS		3		1	2	2			1	19	10	6
CIBICIDES LOBATULUS forma OMASICUS				7	12					2		
CASSIDELLA SP. 1							3					
CASSIDELLA SP. 2												
SUGGRUNDA ECKISI												
LOXOSTOMUM PSEUDOBEYRICHI												
CASSIDULINA DELICATA						1						
CASSIDULINA LIMBATA		1		2	4	4						
GLOBOCASSIDULINA DEPRESSA	1	3	2	1	3	3	7	8	4		3	
GLOBOCASSIDULINA MINUTA	1	1	3									
GLOBOCASSIDULINA SUBGLOBOSA			1		1	1						
CHILOSTOMELLA OVOIDEA												
FLORILUS AURICULUS	13	4	1	2	3	2	2	2	1	2	5	
FLORILUS SCAPHUS BASISPINATUS		2	10	4	1	5	2	2				
NONIONELLA TURGIDA DIGITATA	4		6		1	1						
NONIONELLA STELLA	2	5	2	1	1	1						
NONIONELLINA LABRADORICA			4	1								
PULLENIA SALISBURYI	2	3	1	1		3						
GYROIDINA ALTIFORMIS												
GERATOBULIMINA ARCTICA											3	
GEMINOSPIRA SP.												
GENUS A SPECIES A		1										

Appendix IIb. Relative abundance of species that occur three times or less in the samples studied.

Species name	Sample	%	Sample	%	Sample	%
AGGLUTINATED SPECIES						
HIPPOCREPINA INDIVISA	6911- 7.1	1.0	6911-25.1	1.0	6911-25.2	X
HYPERAMMINA SP.	6907- 2.3	1.0				
PSAMMOSPHAERA DECORATA	6911-10.1	2.0				
SACCAMMINA COMPRIMA	6911- 7.1	1.0	6911- 9.2	X	6911-25.1	1.0
AMMODISCUS SP. 1	6911- 2.5	1.0				
KALAMOPSIS ? SP.	6904-26.2	2.0				
REOPHAX GUTTIFER	6904-10.2	2.0	6904-10.3	3.0		
REOPHAX SCOTTI	6911- 2.1	1.0				
REOPHAX SP.	6911- 8.2	X				
CRIBROSTOMOIDES SP.	6904-26.3	1.0				
TROCHAMMINA GLOBIGERINIFORMIS			6910- 2.2	1.0	6911- 2.1	1.0
TROCHAMMINA INFLATA	6904-26.3	X				
TROCHAMMINA OCHRACEA	6907- 2.1	1.0	6907- 2.2	X	6907- 2.3	1.0
TROCHAMMINA SP.	6910- 2.1	2.0				
GAUDRYINA SUBGLABRATA	6907-26.3	1.0	6911-26.1	5.0	6911-26.3	3.0
MARTINOTTIELLA cf. PRIMAEVA			6904-10.2	2.0	6907-10.3	7.0
GENUS C SPECIES C	6904-10.2	2.0	6907-10.2	6.0		
PORCELANEOUS SPECIES						
CYCLOGYRA INCERTA	6911- 6.4	1.0				
GORDIOSPIRA SP.	6904- 7.2	1.0				
QUINQUELOCULINA cf. Q. AKNERIANA BELLATULA	6910- 2.1	1.0	6911- 2.3	1.0	6911-25.3	1.0
QUINQUELOCULINA SP. 1	6911- 2.6	1.0	6910- 8.1	1.0	6911- 8.3	1.0
QUINQUELOCULINA SP. 2	6910- 2.2	1.0	6911- 2.5	1.0	6907- 8.2	X
QUINQUELOCULINA SP. 3	6904- 8.3	1.0				
TRILOCULINA TRIGONULA	6907- 2.2	1.0	6907- 7.3	X		

(Continued on next page)

Appendix IIb. (Continued)

Species name	Sample	%	Sample	%	Sample	%
HYALINE SPECIES						
DENTALINA cf. D. BAGGI	6911- 2.6	1.0	6911- 9.1	1.0		
DENTALINA ITTAI	6911- 9.2	X	6911-25.3	1.0		
DENTALINA SP. 1	6904- 6.2	X	6901- 8.4	X	6910- 8.2	1.0
DENTALINA SP. 2	6911- 9.3	X				
LENTICULINA SP.	6904- 8.2	1.0	6907- 8.2	X	6911- 8.3	X
LAGENA CAUDATA	6907-26.2	1.0				
LAGENA CLAVATA	6904- 2.2	2.0				
LAGENA COSTATA	6907- 6.3	1.0				
LAGENA DENTALINAFORMIS	6910- 8.3	1.0				
LAGENA ELONGATA	6911- 2.3	1.0				
LAGENA FLEXA	6907-22.3	2.0				
LAGENA GRACILIS	6907- 2.2	X				
LAGENA HISPIDA	6904- 6.2	X	6911-15.1	1.0		
LAGENA SUBMAGNIFICA	6911- 9.1	1.0	6911- 9.3	X		
LAGENA SULCATA PECULIARIS	6907- 2.3	1.0	6910- 8.2	1.0	6911-25.1	1.0
LAGENA SP. 1	6907-26.1	2.0				
LAGENA SP. 3	6911- 9.1	X	6911-15.1	1.0	6911-26.1	2.0
LAGENA SP. 5	6907- 6.1	X	6911- 6.3	1.0	6911-22.2	2.0
LAGENA SP. 6	6911-26.2	3.0				
LAGENA SP. 9	6907- 7.3	X				
LAGENA SP. 11	6904-26.3	1.0				
LAGENA SP. 12	6907- 8.2	X	6911-25.1	1.0	6911-25.2	1.0
MARGINULINA SP.	6907- 6.1	X	6911- 8.1	X	6911- 9.3	1.0
POLYMORPHINA OREGONENSIS	6911-15.2	1.0	6808-26-1.1	1.0	6904-26.2	1.0

(Continued on next page)

Appendix IIb. (Continued)

Species name	Sample	%	Sample	%	Sample	%
HYALINE SPECIES (continued)						
SIGMOMORPHINA TRILOCULARIS	6904-26.3	X				
OOLINA LINEATA	6904-26.3	X				
FISSURINA SP. 1	6901- 8.4	X	6910- 8.1	1.0		
FISSURINA? SP. 2	6910- 8.3	1.0				
UVIGERINA PEREGRINA	6901- 8.4	X	6907- 8.2	X	6808-26-1.3	1.0
TRIFARINA BAGGI	6911-26.1	2.0	6904-26.3	X		
ELPHIDIUM CLAVATUM	6907-15.1	1.0				
ASTRONONION GALLOWAYI	6911-26.1	2.0				
GENUS B SPECIES B	6904-26.3	1.0				
GENUS D SPECIES D	6911-10.3	2.0				
GENUS E SPECIES E	6911-22.2	2.0				

APPENDIX III

FORAMINIFERAL STANDING STOCK IN 20 CC. SAMPLE

The asterisk (*) indicates samples where only 1/2 the sample volume was examined.

Sample		Total	Plank.	Benth.	Agglut.	Porcel.	Hyaline
6901	2.2	36	0	36	12	0	24
6901	2.3	41	0	41	6	0	35
6904	2.1	59	0	59	19	0	40
6904	2.2	55	0	55	5	0	50
6904	2.3	84	0	84	20	0	64
6907	2.1	167	0	167	41	1	125
6907	2.2	262	0	262	49	3	210
6907	2.3	143	0	143	25	1	117
6910	2.1	268	0	268	70	18	180
6910	2.2	390	0	390	92	8	290
6911	2.1	236	0	236	68	2	166
6911	2.2	152	0	152	43	8	101
6911	2.3	181	0	181	51	3	127
6911	2.4	174	1	173	49	18	106
6911	2.5	234	0	234	76	16	142
6911	2.6	185	0	185	25	8	152
6904	6.2	279	11	268	94	1	173
6907	6.1	235	1	234	84	1	149
6907	6.2	106	0	106	36	1	69
6907	6.3	121	1	120	58	0	62
6911	6.1	176	2	174	64	2	108
6911	6.3	74	0	74	28	0	46

(Continued on next page)

Appendix III. (Continued)

Sample		Total	Plank.	Benth.	Agglut.	Porcel.	Hyaline
6911	6.4	127	0	127	40	1	86
6904	7.1	62	0	62	6	0	56
6904	7.2	72	0	72	13	2	57
6904	7.3	82	0	82	15	0	67
6907	7.2	179	0	179	30	0	147
6907	7.3	277	0	277	36	5	236
6911	7.1	263	1	262	54	7	201
6911	7.2	202	0	202	36	1	165
6911	7.3	94	1	93	10	0	83
6901	8.4	290	0	290	38	0	252
6901	8.5*	888	4	884	148	0	736
6901	8.6	152	0	152	31	0	121
6904	8.1	127	0	127	24	1	102
6904	8.2	97	0	97	28	0	69
6904	8.3	89	1	88	38	2	47
6907	8.2	496	0	496	121	6	369
6910	8.1	173	0	173	45	1	127
6910	8.2	146	0	146	35	1	110
6910	8.3	338	0	338	100	2	236
6911	8.1	501	3	498	122	5	371
6911	8.2	326	0	326	68	17	.241
6911	8.3	390	0	390	61	8	321
6911	9.1	250	0	250	104	1	145
6911	9.2	242	0	242	85	10	147
6911	9.3	250	0	250	57	5	188

(Continued on next page)

Appendix III. (Continued)

Sample		Total	Plank.	Benth.	Agglut.	Porcel.	Hyaline
6904	10.1	46	0	46	24	0	22
6904	10.2	41	0	41	18	0	23
6904	10.3	66	1	65	20	1	44
6907	10.2	17	0	17	11	0	6
6907	10.3	15	0	15	12	0	3
6911	10.1	63	1	62	31	1	30
6911	10.2	69	0	69	30	1	38
6911	10.3	126	2	124	55	2	67
6810	15-1.1	72	0	72	37	0	35
6904	15.1	41	0	41	24	0	17
6904	15.2	64	0	64	28	0	36
6904	15.3	31	0	31	13	0	18
6907	15.1	127	1	126	56	0	70
6907	15.5	229	0	229	62	1	166
6910	15.2	196	0	196	118	0	78
6910	15.3	139	0	139	65	0	74
6911	15.1	114	0	114	42	1	71
6911	15.2	74	1	73	39	0	34
6808	22-3.1	17	0	17	16	0	1
6810	22.2	40	1	39	30	0	9
6901	22.1	37	4	33	30	0	3
6901	22.2	10	0	10	9	0	1
6901	22.3	41	0	41	35	0	6
6907	22.1	46	0	46	31	0	15
6907	22.2	38	1	37	22	0	15
6907	22.3	58	0	58	47	0	11

(Continued on next page)

Appendix III. (Continued)

Sample		Total	Plank.	Benth.	Agglut.	Porcel.	Hyaline
6911	22.1	84	0	84	52	0	32
6911	22.2	54	0	54	33	0	21
6911	22.3	46	0	46	29	0	17
6911	25.1	221	0	221	62	1	158
6911	25.2	367	0	367	71	4	292
6911	25.3	160	0	160	23	2	135
6808	26-1.1*	224	0	224	24	0	202
6808	26-1.2	95	0	95	23	0	72
6808	26-1.3*	208	0	208	28	0	180
6904	26.1	176	0	176	40	0	136
6904	26.2*	200	0	200	42	0	158
6904	26.3	370	3	367	125	1	241
6907	26.1	60	0	60	33	0	27
6907	26.2	115	0	115	56	0	59
6907	26.3	163	0	163	84	0	79
6911	26.1	43	0	43	26	0	17
6911	26.2	40	0	40	23	0	17
6911	26.3	31	0	31	22	0	9

APPENDIX IV

ENVIRONMENTAL VARIABLES

The values of the environmental variables are shown on separate pages. Zero values indicate that either no sample was collected, or that the collected sample was not processed for that ecologic variable.

Cruise numbers "6808" and "6810" are repeated for the substations "-A, -B, -C" and "Center, -A, -B, -C" respectively.

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

1 WATER DEPTH IN METERS

CRUISE	STATIONS 2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	198.00	235.00	148.00	154.00	95.00	199.00	134.00	459.00	139.00	75.00	75.00	102.00	128.00	124.00	124.00
6808	234.00	244.00	150.00	154.00	100.00	198.00	155.00	549.00	139.00	81.00	76.00	102.00	131.00	124.00	138.00
6808	205.00	0	176.00	150.00	95.00	192.00	154.00	0	101.00	0	75.00	110.00	131.00	125.00	124.00
6810	204.00	0	0	145.00	100.00	208.00	0	532.00	0	0	75.00	104.00	0	0	0
6810	0	0	0	0	0	0	0	494.00	104.00	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	494.00	109.00	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	97.00	0	0	0	0	0	0
6901	200.00	0	0	146.00	0	200.00	0	0	100.00	0	73.00	0	0	0	0
6904	189.00	240.00	150.00	150.00	100.00	200.00	150.00	443.00	102.00	75.00	0	102.00	128.00	125.00	121.00
6907	183.00	236.00	150.00	150.00	99.00	183.00	153.00	452.00	100.00	80.50	73.00	102.00	124.00	125.00	125.00
6910	197.50	0	0	0	0	212.00	0	0	100.00	0	0	0	0	0	0
6911	197.50	244.00	150.00	144.50	100.00	200.00	150.00	431.60	100.00	0	75.00	100.00	130.00	125.00	127.00
7002	200.00	0	0	150.00	98.00	200.00	150.00	482.70	100.00	0	0	100.00	130.00	125.00	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

2 WATER TEMPERATURE IN DEGREES CENTIGRADE

CRUISE	STATIONS														
	2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	7.85	6.67	7.11	6.57	6.93	6.61	0	0	6.54	5.54	8.22	6.96	6.79	6.78	7.36
6808	8.01	0	7.11	6.67	6.94	6.72	0	0	6.57	0	7.32	6.97	6.79	6.78	0
6808	8.04	0	7.11	6.73	6.93	0	0	0	6.63	0	0	6.97	6.79	6.78	7.45
6810	7.66	0	0	8.01	8.20	8.26	0	7.54	8.09	0	8.67	8.24	0	0	0
6810	0	0	0	0	0	0	0	5.82	8.18	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	5.47	8.05	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	8.82	0	0	0	0	0	0
6901	7.89	0	0	8.54	0	7.90	0	0	8.71	0	9.04	0	0	0	0
6904	7.12	0	7.50	7.09	7.13	6.78	7.40	0	7.65	8.10	0	7.63	7.63	7.57	7.52
6907	6.11	6.35	6.94	6.38	7.04	6.47	6.84	5.52	7.02	7.38	6.70	7.18	0	7.25	6.85
6910	7.61	0	0	0	0	8.02	0	0	8.83	0	0	0	0	0	0
6911	8.19	7.65	8.43	8.20	12.04	12.04	12.44	5.61	8.78	0	9.21	8.88	8.49	8.64	8.75
7002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

UNDERLINED VALUES CALCULATED AS A FUNCTION OF OTHER HYDROGRAPHIC VALUES

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

3 WATER SALINITY IN 0/00

CRUISE	STATIONS														
	2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	33.930	33.880	33.922	33.854	33.831	33.947	0	34.108	33.878	0	0	33.819	33.897	33.869	33.810
6808	33.870	33.890	33.870	33.895	33.810	33.912	33.880	34.137	33.910	33.872	0	33.552	33.896	33.849	0
6808	33.920	0	33.912	33.901	33.811	33.942	33.912	0	33.810	0	33.786	33.835	33.909	33.877	33.680
6810	33.894	0	0	33.800	32.821	33.822	0	33.925	0	0	33.478	33.694	0	0	0
6810	0	0	0	0	0	0	0	34.014	33.742	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	34.089	33.736	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	33.764	0	0	0	0	0	0
6901	33.869	0	0	33.519	0	33.822	0	0	33.385	0	32.678	0	0	0	0
6904	33.958	0	33.902	34.010	33.784	34.018	33.949	33.869	33.736	33.282	33.157	33.743	33.874	33.890	33.935
6907	34.039	34.029	33.976	34.035	33.987	34.027	33.990	34.127	34.014	33.902	33.989	33.969	33.997	34.001	33.956
6910	0	0	0	0	0	33.920	0	0	33.845	0	0	0	0	0	0
6911	33.348	0	0	33.863	33.736	32.968	33.800	33.791	33.342	0	33.690	33.652	0	0	0
7002	33.966	0	0	33.644	32.875	33.980	0	33.904	33.027	0	32.386	33.325	0	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

4 SEDIMENT MEDIAN GRAIN SIZE IN PHI UNITS (Q(2))

CRUISE	STATIONS														
	2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	3.426	5.298	3.413	5.682	3.012	6.259	0	1.484	2.947	2.279	2.242	5.202	3.439	3.249	2.798
6808	3.529	2.699	1.926	6.006	3.510	6.870	3.218	2.601	2.860	2.246	2.008	5.677	3.253	3.940	2.340
6808	0	0	2.069	5.891	3.003	6.817	0	0	2.716	0	2.008	4.512	3.171	4.407	2.476
6810	3.467	0	0	6.310	3.249	6.652	0	2.581	0	0	1.699	5.132	0	0	0
6810	0	0	0	0	0	0	0	4.691	2.826	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	1.639	2.968	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	2.678	0	0	0	0	0	0
6901	3.473	0	0	6.124	0	6.262	0	0	2.597	0	2.062	0	0	0	0
6904	3.484	4.379	3.241	5.374	3.945	6.631	3.094	1.585	2.742	2.226	0	5.238	3.329	4.178	1.817
6907	3.178	5.884	3.535	5.680	3.242	4.981	0	0	4.505	2.189	1.914	4.012	3.102	4.047	2.699
6910	2.858	0	0	0	0	6.089	0	0	2.588	0	0	0	0	0	0
6911	3.360	2.492	.987	5.354	3.713	0	2.920	1.877	2.524	0	0	5.035	3.226	0	2.570
7002	2.737	0	0	5.730	3.105	6.227	3.038	2.193	4.760	0	0	4.982	3.063	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

5 SEDIMENT WEIGHT-PERCENT CALCIUM CARBONATE

CRUISE	STATIONS														
	2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	.113	.068	.113	.028	.046	.071	0	.014	.009	.045	0	.009	0	.020	1.090
6808	.091	0	.136	.046	.040	0	.028	.072	.049	.031	.027	.049	.049	.123	.213
6808	.037	0	.036	.069	.019	.027	0	0	.002	0	.018	.027	0	.189	.154
6810	.047	0	0	.028	.111	.098	0	.046	.042	0	.024	.042	0	0	0
6810	0	0	0	0	0	0	0	.041	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6901	.047	0	0	.042	0	.093	0	0	.009	0	0	0	0	0	0
6904	.052	0	.042	.051	.046	.084	0	.014	.028	0	.028	.069	.009	.033	0
6907	.047	0	0	.070	.014	.074	0	0	0	0	.019	.028	0	0	0
6910	.056	0	0	0	0	.089	0	0	.028	0	0	0	0	0	0
6911	.037	.410	0	.066	.046	.061	.019	0	.033	0	0	.074	.019	0	0
7002	.077	0	0	.080	.030	.105	0	.010	0	0	0	.046	0	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

6 SEDIMENT WEIGHT-PERCENT SAND

CRUISE	STATIONS 2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	70.72	25.20	84.33	12.02	80.43	5.81	0	92.26	86.15	97.03	99.04	28.99	63.13	89.30	92.19
6808	67.62	62.73	82.85	2.59	59.86	1.23	64.58	84.09	84.21	98.55	96.80	22.00	68.00	51.31	96.47
6808	0	0	84.63	4.46	77.01	1.66	0	0	86.36	0	98.54	37.06	77.40	42.01	96.35
6810	67.65	0	0	1.23	61.81	1.38	0	62.74	0	0	100.00	23.75	0	0	0
6810	0	0	0	0	0	0	0	43.06	79.10	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	78.92	64.04	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	86.35	0	0	0	0	0	0
6901	70.49	0	0	1.45	0	2.04	0	0	86.97	0	97.41	0	0	0	0
6904	65.00	44.02	81.55	7.60	51.30	1.29	64.63	84.64	84.07	95.44	100.00	20.84	67.51	46.51	92.19
6907	86.31	8.79	56.96	2.26	69.51	15.24	0	80.00	37.15	99.80	98.76	49.84	81.14	49.00	94.43
6910	94.52	0	0	0	0	2.05	0	0	82.82	0	0	0	0	0	0
6911	83.49	75.02	67.40	6.95	56.77	0	70.99	81.90	88.15	0	100.00	24.43	67.48	0	97.83
7002	77.83	0	0	3.29	72.26	1.61	67.82	67.57	0	0	0	31.32	79.06	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

7 SEDIMENT WEIGHT-PERCENT SILT

CRUISE	STATIONS 2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	14.83	50.54	7.16	59.26	13.01	64.69	0	4.99	4.80	.63	.22	47.75	27.05	7.51	3.24
6808	17.13	2.28	7.52	67.18	27.12	57.79	21.13	6.94	14.02	.33	3.20	46.29	22.92	31.95	3.53
6808	0	0	5.97	65.68	14.84	56.96	0	0	8.84	0	.51	43.32	14.43	37.60	1.24
6810	16.68	0	0	64.07	24.84	59.14	0	21.11	0	0	0	49.62	0	0	0
6810	0	0	0	0	0	0	0	31.11	11.67	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	11.91	22.86	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	5.82	0	0	0	0	0	0
6901	16.76	0	0	65.09	0	64.15	0	0	7.45	0	.53	0	0	0	0
6904	18.92	33.41	6.82	64.53	31.50	60.46	21.04	7.40	10.66	.04	0	50.99	19.95	35.74	3.24
6907	10.95	65.64	23.60	72.63	20.92	70.35	0	10.00	44.62	.20	.50	34.28	13.56	35.71	2.26
6910	2.61	0	0	0	0	67.29	0	0	12.25	0	0	0	0	0	0
6911	13.90	12.50	19.43	70.67	33.14	0	20.20	12.11	8.01	0	0	52.59	22.20	0	.83
7002	15.95	0	0	76.74	21.24	68.14	22.39	27.45	0	0	0	47.30	15.17	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

8 SEDIMENT WEIGHT-PERCENT CLAY

CRUISE	STATIONS													
	2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	14.46	24.25	8.51	28.72	6.56	29.50	0	2.74	9.05	2.35	.73	23.26	9.82	3.20	4.57
6808	15.25	4.99	9.63	30.22	13.01	40.98	14.29	8.96	1.76	1.13	0	31.71	9.07	16.74	0
6808	0	0	9.40	29.86	8.15	41.38	0	0	4.80	0	.95	19.63	8.17	20.39	2.41
6810	15.67	0	0	34.70	13.35	39.72	0	16.15	0	0	0	26.64	0	0	0
6810	0	0	0	0	0	0	0	25.83	9.23	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	9.17	13.09	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	7.83	0	0	0	0	0	0
6901	12.75	0	0	33.47	0	33.81	0	0	5.58	0	2.07	0	0	0	0
6904	16.08	22.57	11.63	27.86	17.20	38.25	14.32	7.96	5.27	4.52	0	28.17	12.54	17.75	4.57
6907	2.73	25.58	19.45	25.11	9.57	14.42	0	10.00	18.23	0	.73	15.88	5.30	15.30	3.32
6910	2.86	0	0	0	0	30.66	0	0	4.94	0	0	0	0	0	0
6911	2.60	12.47	13.17	22.38	10.09	0	8.81	5.99	3.84	0	0	22.98	10.32	0	1.34
7002	6.22	0	0	19.97	6.50	30.25	9.79	4.98	0	0	0	21.38	5.77	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

9 SEDIMENT SORTING COEFFICIENT (FOLK-WARD)

CRUISE	STATIONS 2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	2.61	3.01	2.24	3.17	1.49	2.06	0	1.28	2.30	.42	.56	2.69	2.52	.83	1.22
6808	3.01	1.15	2.42	2.34	2.44	2.84	2.68	1.83	1.04	.36	.52	2.99	1.85	2.52	.53
6808	0	0	2.87	2.59	1.63	3.22	0	0	1.29	0	.43	3.27	1.64	3.42	.48
6810	3.05	0	0	2.68	2.68	3.13	0	3.11	0	0	.48	3.29	0	0	0
6810	0	0	0	0	0	0	0	3.60	2.27	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	2.63	2.57	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	2.16	0	0	0	0	0	0
6901	2.17	0	0	2.73	0	2.61	0	0	1.25	0	.44	0	0	0	0
6904	3.24	3.22	2.47	2.91	2.88	2.79	2.88	2.39	1.40	.50	.40	3.19	2.79	2.87	1.22
6907	.71	4.08	3.07	2.22	2.20	1.83	0	2.20	2.62	.38	.43	3.30	1.33	2.59	.58
6910	.67	0	0	0	0	2.71	0	0	1.45	0	0	0	0	0	0
6911	.72	2.61	3.92	1.96	1.95	0	2.18	2.01	.99	0	.43	2.57	1.91	0	.32
7002	1.66	0	0	1.86	1.48	2.26	2.17	2.20	0	0	0	2.52	1.43	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

10 SEDIMENT AVERAGE GRAIN SIZE (FOLK-WARD)

CRUISE	STATIONS 2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	4.522	5.956	3.480	6.913	3.401	6.633	0	1.470	3.006	2.177	2.118	6.072	4.046	3.309	2.696
6808	4.689	2.732	2.505	6.756	4.332	7.558	4.313	2.763	3.062	2.404	2.008	6.613	3.914	5.032	2.313
6808	0	0	2.415	6.821	3.537	7.825	0	0	2.722	0	2.005	5.791	3.613	5.766	2.457
6810	4.761	0	0	7.137	4.216	7.693	0	4.026	0	0	1.660	6.479	0	0	0
6810	0	0	0	0	0	0	0	5.513	3.332	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	2.659	3.982	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	2.699	0	0	0	0	0	0
6901	4.373	0	0	7.118	0	7.065	0	0	2.597	0	2.043	0	0	0	0
6904	4.853	5.684	3.581	6.679	5.090	7.488	4.139	1.915	3.006	2.162	1.700	6.496	3.996	5.212	2.696
6907	3.231	7.760	4.761	6.450	3.906	5.586	0	2.500	5.381	2.165	1.930	4.888	3.393	4.951	2.665
6910	2.776	0	0	0	0	7.045	0	0	2.954	0	0	0	0	0	0
6911	3.492	3.713	2.366	6.056	4.155	0	3.545	2.422	2.515	0	1.630	5.854	4.086	0	2.560
7002	3.271	0	0	6.216	3.568	6.829	3.771	3.052	0	0	0	5.666	3.446	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

14 SEDIMENT WEIGHT-PERCENT TOTAL CARBCN

CRUISE	STATIONS														
	2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6809	1.27	.98	.97	1.74	.54	1.67	0	.53	.45	0	0	1.52	.71	1.09	1.64
6809	1.43	0	.79	1.95	.65	0	.61	2.01	.47	.07	.26	1.33	.64	.93	.76
6809	1.07	0	.70	1.80	.43	1.94	0	0	0	0	0	1.09	0	1.13	.74
6810	1.05	0	0	1.71	.62	1.57	0	.84	.42	0	.07	1.30	0	0	0
6810	0	0	0	0	0	0	0	1.08	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	.52	.71	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	.31	0	0	0	0	0	0
6901	1.08	0	0	1.86	0	1.74	0	0	.36	0	0	0	0	0	0
6904	1.21	0	.86	1.48	.65	1.94	0	.36	.44	0	.18	1.40	.59	.96	1.64
6907	.78	0	0	1.89	.74	1.55	0	.49	0	0	.10	1.51	0	0	0
6910	1.02	0	0	0	0	1.92	0	0	.54	0	0	0	0	0	0
6911	.91	1.48	.80	1.75	.79	1.99	0	.56	.44	0	.10	1.34	.80	0	0
7002	1.16	0	0	1.92	.55	2.04	0	1.12	0	0	0	1.30	0	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

15 SEDIMENT WEIGHT-PERCENT ORGANIC CARBON

CRUISE	STATIONS 2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	1.16	.91	.86	1.71	.49	1.60	0	.52	.44	0	0	1.51	0	1.07	0
6808	1.34	0	.65	1.90	.61	0	.58	1.94	.42	.04	.24	1.28	.59	.35	.54
6808	1.03	0	.67	1.73	.41	1.91	0	0	0	0	0	1.06	0	.94	.59
6810	.99	0	0	1.65	.53	1.47	0	.79	.37	0	.05	1.26	0	0	0
6810	0	0	0	0	0	0	0	1.04	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	.52	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6901	1.03	0	0	1.82	0	1.57	0	0	.36	0	0	0	0	0	0
6904	1.16	0	.82	1.43	.60	1.86	0	.35	.42	0	.15	1.33	.58	.93	0
6907	.26	0	0	1.82	.74	1.48	0	.49	0	0	.08	1.48	0	0	0
6910	.96	0	0	0	0	1.83	0	0	.51	0	0	0	0	0	0
6911	.87	1.07	0	1.68	.75	1.93	0	.56	.41	0	.11	1.27	.79	0	0
7002	1.08	0	0	1.84	.58	1.93	0	1.11	0	0	0	1.25	0	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

16 SEDIMENT ORGANIC NITROGEN IN MILLIGRAMS/G SEDIMENT

CRUISE	STATIONS 2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6808	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6808	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	1.034	0	0	1.885	.548	1.550	0	.927	0	0	.008	1.160	0	0	0
6810	0	0	0	0	0	0	0	0	.468	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6901	1.015	0	0	1.675	0	1.720	0	0	.446	0	0	0	0	0	0
6904	1.170	0	0	1.390	.215	1.765	0	.565	.397	0	.011	.862	0	0	0
6907	1.210	0	0	1.710	.667	1.455	0	.537	.497	0	.012	.922	0	0	0
6910	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6911	.121	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7002	.123	0	0	0	.565	0	0	.498	0	0	.012	0	0	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

17 WATER OXYGEN CONCENTRATION IN ML/L

CRUISE	STATIONS														
	2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	2.15	2.51	1.92	1.74	1.95	2.16	0	1.48	1.66	1.14	2.44	1.98	1.84	1.81	2.82
6808	2.09	0	2.20	1.82	1.95	2.23	0	1.48	1.67	1.12	2.44	1.98	1.76	1.81	2.76
6808	2.13	0	2.57	1.88	1.95	2.12	0	0	1.67	0	2.44	1.98	1.76	1.81	2.76
6810	2.49	0	0	2.31	3.15	2.54	0	2.39	0	0	3.87	3.12	0	0	0
6810	0	0	0	0	0	0	0	1.51	2.13	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	1.06	2.13	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	2.37	0	0	0	0	0	0
6901	2.98	0	0	4.13	0	3.08	0	0	4.08	0	5.59	0	0	0	0
6904	2.34	0	2.53	2.10	1.83	2.08	2.37	2.98	2.63	3.94	0	2.60	2.50	2.45	2.82
6907	1.52	1.47	2.21	1.65	1.96	1.90	1.88	.87	1.57	2.37	1.57	2.23	1.35	1.73	2.18
6910	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6911	2.30	0	3.24	2.62	3.41	0	2.92	1.50	3.80	0	2.28	2.75	0	0	3.21
7002	2.34	0	0	2.58	5.61	2.29	0	1.23	4.62	0	6.28	0	0	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

19 WATER PHOSPHATE CONCENTRATION IN MICROMOLES/L

CRUISE	STATIONS 2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	2.51	2.60	2.05	2.69	2.63	2.58	0	3.02	2.66	2.79	2.43	2.60	2.67	2.46	3.34
6808	2.72	0	2.50	2.37	2.63	2.69	0	3.02	2.33	2.81	2.43	2.60	2.67	2.46	2.25
6808	2.56	0	62.35	2.75	2.63	2.52	0	0	2.60	0	2.43	2.60	2.67	2.46	2.25
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6901	2.08	0	0	1.78	0	2.35	0	0	1.50	0	1.19	0	0	0	0
6904	2.89	0	2.55	3.24	3.03	3.10	2.63	2.75	2.79	1.84	0	2.89	2.55	2.57	3.34
6907	0	2.50	2.46	0	3.89	3.12	3.09	3.17	2.79	0	2.77	0	3.15	0	3.32
6910	0	0	0	0	0	2.49	0	0	2.72	0	0	0	0	0	0
6911	1.91	0	2.23	2.33	3.05	2.16	0	2.70	1.98	0	1.89	3.09	0	3.34	2.35
7002	2.33	0	0	3.03	2.03	3.92	0	1.70	2.18	0	1.83	2.31	0	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

20 WATER SILICATE CONCENTRATION IN MICROMOLES/L

CRUISE	STATIONS														
	2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	51.60	51.60	52.00	51.60	50.10	54.70	0	79.50	56.40	60.00	45.80	52.50	55.80	53.10	45.40
6808	54.00	0	52.00	53.80	50.10	52.20	0	79.50	57.10	60.50	45.80	52.50	55.80	53.60	45.10
6808	55.60	0	54.20	54.00	50.10	53.60	0	0	55.00	0	45.80	52.50	55.80	53.60	45.10
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6901	32.25	0	0	23.84	0	30.99	0	0	21.19	0	11.08	0	0	0	0
6904	40.83	0	39.58	47.09	47.07	48.23	40.77	33.20	40.56	24.36	0	39.91	36.06	39.61	45.40
6907	54.00	45.00	49.00	0	56.00	58.00	45.00	51.00	63.00	0	59.00	50.00	56.00	53.00	65.00
6910	0	0	0	0	0	43.41	0	0	41.70	0	0	0	0	0	0
6911	29.00	0	35.00	39.00	40.00	19.00	41.00	57.00	3.00	0	34.00	34.00	0	0	36.00
7002	21.00	0	0	27.00	15.00	38.00	0	32.00	17.00	0	10.00	21.00	0	0	0

SEA GRANT BENTHIC ECOLOGY --- OREGON SHELF

21 WATER NITRATE CONCENTRATION IN MICROMOLES/L

CRUISE	STATIONS 2	3	4	6	7	8	9	10	15	21	22	23	24	25	26
6808	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6808	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6808	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6810	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6901	27.47	0	0	25.40	0	25.77	0	0	14.08	0	5.76	0	0	0	0
6904	28.67	0	30.65	31.70	28.10	33.35	30.63	27.33	26.08	17.40	0	26.49	29.56	29.63	0
6907	34.10	27.10	30.80	0	33.10	33.40	33.20	32.20	34.00	0	31.20	31.00	33.50	29.50	35.20
6910	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6911	21.30	0	25.70	28.40	26.60	11.50	27.60	20.00	23.10	0	25.60	24.20	0	0	27.70
7002	14.80	0	0	17.80	9.40	24.50	0	20.00	11.21	0	6.60	17.00	0	0	0

APPENDIX V

LOGNORMAL FREQUENCY ANALYSIS

The number of species with frequencies within each frequency class interval is shown. A lognormal distribution is indicated if the numbers for any one sample are the same or very similar.

Sample X^2 - contingency	Class A 1	B 2-4	C 5-13	D 14-40	E 41-120	F 121-364
Combined data	942	748	423	156	37	5
6904 - 2.1	8	7	2	1		
.2	10	3	2	1		
.3	10	3	3		1	
5.846						
6907 - 2.1	10	8	3	1	1	
.2	11	7	8	2		1
.3	14	9	4		1	
7.694						
6910 - 2.1	12	11	4	1	1	
.2	6	16	5	1	1	
6911 - 2.1	13	12	3		1	
.2	19	14	5	2	1	
.3	17	16	10	2	1	
.4	14	11	7	1	1	
.5	14	9	5		1	
.6	13	12	4	1	1	
6.729						

(Continued on next page)

Appendix V. (Continued)

Sample X^2 - contingency	Class A 1	B 2-4	C 5-13	D 14-40	E 41-120	F 121-364
6907 - 6.1	14	15	5	5		
.2	6	9	6	5	2	
.3	10	7	5	2		
3.114						
6911 - 6.1	12	8	7	4		
.3	8	8	6			
.4	10	8	10	1		
5.400						
6904 - 7.1	8	2	5	1		
.2	11	7	5			
.3	13	7	3	1		
4.446						
6911 - 7.1	12	13	8	4	1	
.2	15	11	2	4	1	
.3	15	2	4	2		
11.204						
6901 - 8.4	14	8	7	2	2	
.5	14	8	7	5		1
.6	9	7	6	4		
7.181						
6904 - 8.1	7	6	5	1	1	
.2	5	9	2	3		
.3	9	8	5	1		
6.655						

(Continued on next page)

Appendix V. (Continued)

Sample	Class					
	A	B	C	D	E	F
X^2 - contingency	1	2-4	5-13	14-40	41-120	121-364
6910 - 8.1	8	14	2	2	1	
.2	12	10	5	1	1	
.3	11	11	4	4		
5.700						
6911 - 8.1	11	9	12	7		1
.2	12	8	9	3	2	
.3	14	12	7	5		1
8.908						
6911 - 9.1	13	11	9	6		
.2	22	7	6	6		
.3	14	13	9	5		
5.538						
6904 -10.1	7	8	2			
.2	11	7	2			
.3	13	7	5			
2.310						
6911 -10.1	8	10	4			
.2	17	8	4			
.3	13	10	5	2		
6.189						
6904 -15.1	8	7	2			
.2	12	8	1	1		
.3	7	8	1			
2.875						
6907 -15.1	6	14	8	1		
.5	11	13	10	2	1	
2.125						

(Continued on next page)

Appendix V. (Continued)

Sample	Class					
	A	B	C	D	E	F
X^2 - contingency	1	2-4	5-13	14-40	41-120	121-364
6901 -22.1	4	2	3			
.2	3	1	1			
.3	6	2		1		
4.871						
6907 -22.1	6	5	1	1		
.2	5	3	3			
.3	8	2		2		
7.706						
6911 -22.1	10	3	3	2		
.2	5	4	2	1		
.3	4	4	2	1		
1.952						
6911 -25.1	12	14	11	4		
.2	13	14	5	8	1	
.3	11	6	8	3		
7.769						
6904 -26.1	14	14	6		1	
.2	14	10	4	1		
.3	15	17	16	1	2	
7.529						
6808 -26.1	7	5	3	1	1	
.2	12	10	3	1		
.3	16	8	3		1	
4.350						

(Continued on next page)

Appendix V. (Continued)

Sample	Class					
	A	B	C	D	E	F
X^2 - contingency	1	2-4	5-13	14-40	41-120	121-364
6907 -26.1	9	9	4			
.2	8	7	8	1		
.3	12	4	9	3		
7.485						
6911 -26.1	11	4	1	1		
.2	6	5	3			
.3	9	6	1			
5.209						

APPENDIX VI

RESULTS OF REGRESSION ANALYSIS OF FORAMINIFERAL FAUNAL PARAMETERS FROM SEA GRANT STATIONS

The regression equation is presented for the minimum value of the standard deviation of Y. Underlined coefficients are not significantly different than zero. The coefficient at step zero is the constant of the regression.

Step	Coefficient	Dependent Variable (Y) Independent Variable (X_i)	R^2
		Count of living benthic foraminifers	
0	12.29395		
1	+ 1.804	Depth in meters	18.13
2	-139.08	Sediment sorting	23.48
3	+ <u>0.853</u>	$(\text{Temperature})^2$	27.96
4		[deleted below]	30.53
5	- 3.4995	Water nitrate	31.70
6	+ <u>0.0233</u>	$(\text{Water silicate})^2$	32.82
7	+ 34.884	$(\text{Water phosphate})^2$	34.20
8	+ 6.781	Percent silt	37.39
9	-138.86	$(\text{Sediment organic carbon})^2$	41.59
10	- 45.15	Median grain size, ϕ	43.25
11		[delete above]	43.21
12	+ <u>0.1184</u>	$(\text{Sediment percent clay})^2$	44.98
13	+ <u>67.08</u>	Sediment total carbon	46.67

Appendix VI. (Continued)

Step	Coefficient	Dependent variable (Y) Independent variable (X_i)	R^2
		Count of living agglutinated foraminifers	
0	29.878		
1	- 7.49	Water oxygen	10.38
2	+ 4.762	Temperature	16.21
3	+ 0.0165	(Sediment percent silt)^2	19.75
4	-16.25	Average grain size, ϕ	26.71
5	+ 1.807	(Sediment sorting)^2	32.44
6		[deleted below]	36.29
7	+ 0.375	Depth in meters	38.18
8	-26.863	Sediment total carbon	39.85
9	- 1.11	Water nitrate	41.66
10		[delete above]	41.65
11	+ 0.55	Water silicate	43.44
12	- 0.022	(Sediment percent clay)^2	44.91

Appendix VI. (Continued)

Step	Coefficient	Dependent variable (Y) Independent variable (X_i)	R^2
		Count of living hyaline foraminifers	
0	114.0794		
1	+ 1.1408	Depth in meters	18.13
2	-184.156	Sediment sorting	23.48
3	+ 1.0594	$(\text{Temperature})^2$	27.96
4		[deleted below]	30.53
5	- 5.326	Water nitrate	31.70
6	+ 0.0461	$(\text{Water silicate})^2$	32.82
7	+ 46.683	$(\text{Sediment sorting})^2$	34.20
8	+ 6.792	Sediment percent sand	37.39
9	-219.214	$(\text{Sediment organic carbon})^2$	41.59
10	- 50.728	Median grain size, ϕ	43.24
11		[delete above]	43.21
12	+ 0.1719	$(\text{Sediment percent clay})^2$	44.98
13	+252.575	Sediment total carbon	44.67
14	-302.294	Sediment percent carbonate	49.17
15	- 0.0574	$(\text{Salinity})^2$	50.41

Appendix VI. (Continued)

Step	Coefficient	Dependent variable (Y) Independent variable (X_i)	R^2
		Log_{10} (Count of living benthic foraminifers)	
0	5.09555		
1	-0.000265	(Sediment percent sand)^2	23.47
2	-0.11375	Water oxygen	32.74
3	+0.03159	Temperature	39.23
4	+0.00589	Depth in meters	43.75
5	-0.50144	Average grain size, ϕ	52.17
6	+0.4209	(Sediment percent carbonate)^2	56.36
7	+0.00089	(Sediment percent clay)^2	57.84
8	-0.1871	(Sediment organic carbon)^2	60.64
9	-0.140	Sediment sorting	62.90
10	-0.0116	Water silicate	64.50
11	+0.00016	(Water silicate)^2	65.84
12	-0.00887	(Water oxygen)^2	66.65

Appendix VI. (Continued)

Step	Coefficient	Dependent variable (Y) Independent variable (X_i)	R^2
		Log_{10} (Count of agglutinated foraminifers)	
0	-9.510		
1	+5.148	Sediment sorting	90.62
2	+0.0008	$(\text{Percent sand})^2$	95.78
3	+0.0009	$(\text{Percent silt})^2$	97.42
4	-1.269	Sediment percent carbonate	98.00
5	+0.0364	Water nitrate	98.14
6	+0.0006	$(\text{Percent clay})^2$	98.22
7	-0.940	Sediment organic carbon	98.28
8	+0.00004	$(\text{Depth in meters})^2$	98.43
9	-0.134	Water phosphate	98.53
10	-0.02335	Water silicate	98.59
11	-0.012	Salinity	98.65
12	-0.0572	Sediment organic nitrogen	98.72
13	-0.133	Temperature	98.89

Appendix VI. (Continued)

Step	Coefficient	Dependent variable (Y) Independent variable (X_i)	R^2
		Log_{10} (Count of living hyaline foraminifers)	
0	5.09555		
1	-0.00027	(Sediment percent sand)^2	23.47
2	-0.1137	Water oxygen	32.74
3	+0.0316	Temperature	39.23
4	+0.00589	Depth in meters	43.75
5	-0.5014	Average grain size, ϕ	52.17
6	+0.421	(Sediment percent carbonate)^2	56.36
7	+0.00089	(Sediment percent clay)^2	57.84
8	-0.1871	(Sediment organic carbon)^2	60.64
9	-0.140	Sediment sorting	62.90
10	-0.0116	Water silicate	64.50
11	+0.00016	(Water silicate)^2	65.84
12	-0.00887	(Median grain size)^2	66.65

Appendix VI. (Continued)

Step	Coefficient	Dependent variable (Y) Independent variable (X_i)	R^2
		Fraction agglutinated foraminifers	
0	0.50820		
1		[deleted below]	32.99
2	-0.002424	Depth in meters	50.96
3	-0.33241	(Percent carbonate)^2	58.14
4	+0.01325	(Sediment sorting)^2	61.81
5	-0.018566	Temperature	65.27
6		[deleted below]	68.06
7	-0.009277	(Water phosphate)^2	69.53
8	+0.11063	(Sediment organic carbon)^2	70.65
9	+0.0000431	(Percent sand)^2	74.77
10	-0.002472	Salinity	76.62
11	+0.0000825	(Water silicate)^2	78.26
12	-0.004951	Water nitrate	79.08
13		[delete above]	79.07
14	+0.0000856	(Percent clay)^2	79.36
15	+0.000451	(Month of cruise)^2	79.69
16		[delete above]	79.68

Appendix VI. (Continued)

Step	Coefficient	Dependent variable (Y) Independent variable (X_i)	R^2
		Fraction hyaline foraminifers	
0	0.505440		
1		[deleted below]	33.87
2	+0.00233	Depth in meters	50.56
3	+0.34298	(Percent carbonate)^2	58.46
4	-0.01288	(Water oxygen)^2	61.99
5	+0.01692	Temperature	64.87
6		[deleted below]	67.91
7	+0.009361	(Water phosphate)^2	69.56
8	-0.11123	(Sediment organic carbon)^2	70.64
9	-0.0000435	(Percent sand)^2	74.88
10	+0.002569	Salinity	77.07
11	-0.0000832	(Water silicate)^2	78.61
12	+0.005168	Water nitrate	79.52
13		[delete above]	79.51
14	-0.000084	(Percent clay)^2	79.78
15	-0.000475	(Month of cruise)^2	80.15
16		[delete above]	80.14

Appendix VI. (Continued)

Step	Coefficient	Dependent variable (Y) Independent variable (X_i)	R^2
		Hyaline/agglutinated ratio	
0	-2.9823		
1	+0.631	Sediment sorting	17.55
2	+1.885	Percent carbonate	30.41
3		[deleted below]	33.76
4	+0.0740	$(\text{Water phosphate})^2$	36.90
5	-0.0008845	$(\text{Percent silt})^2$	39.28
6	+1.0701	Average grain size, ϕ	45.78
7	-0.00251	$(\text{Percent clay})^2$	49.84
8	-1.341	Sediment total carbon	52.05
9		[delete above]	52.04
10	+0.0066	$(\text{Temperature})^2$	52.85

Appendix VI. (Continued)

Step	Coefficient	Dependent variable (Y) Independent variable (X_i)	R^2
		Diversity (Simpson), benthic foraminifers	
0	0.6817		
1	+0.0107	Month of cruise	17.47
2	+0.0145	Sediment sorting	33.39
3	-0.00002	(Water silicate)^2	38.10
4	-0.000365	Hyaline count	42.28
5	+0.0292	Median grain size, ϕ	46.38
6	+0.00103	Agglutinated count	51.07
7	-0.000003	(Depth in meters)^2	54.62
8	+0.00523	(Water phosphate)^2	55.93
9	+0.00228	Water nitrate	57.80
10	-0.0269	Water oxygen	60.27
11	-0.00003	(Salinity)^2	61.41
12	+0.00544	Temperature	64.43

Appendix VI. (Continued)

Step	Coefficient	Independent variable (X_i)	R^2
		Dependent variable (Y)	
		Diversity (Shannon), benthic foraminifers	
0	-5.501		
1	+3.993	Fraction agglutinated	40.06
2	+4.032	Fraction hyaline	86.15
3	+0.00314	Agglutinated count	90.14
4	+0.0753	Temperature	90.44
5	+0.0463	Median grain size, ϕ	90.73
6	-0.0132	Sediment organic nitrogen	91.73
7	-0.00468	$(\text{Temperature})^2$	92.01
8	-0.198	Sediment organic carbon	92.15
9	-0.00004	$(\text{Sediment percent sand})^2$	92.29
10	+0.00153	Depth in meters	92.51
11	+0.00387	Salinity	92.86
12	-0.0222	Water phosphate	93.09
13	+0.096	Sediment total carbon	93.21
14	-0.00005	$(\text{Sediment percent silt})^2$	93.42
15	+0.0085	Median grain size, ϕ	93.56
16	-0.000007	$(\text{Water silicate})^2$	93.58

APPENDIX VII

RESULTS OF REGRESSION ANALYSIS OF FORAMINIFERAL FAUNAL PARAMETERS FROM INDIVIDUAL SEASONAL STATIONS

The value of the regression constant and of the coefficients for the independent variables are given for each step. Underlined coefficients do not differ significantly from zero (5% level of significance).

Appendix VII-a. Results from seasonal station SG-22. Data from 11 samples.

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Count of living benthic foraminifers				
56.87	Sediment organic carbon	22.215	+3358.6		
60.22	(Percent carbonate)^2	2.896	+4785.0	+37330.	
	Count of living agglutinated foraminifers				
31.58	Sediment organic carbon	16.295	+200.99		
32.65	Percent clay	19.581	+175.7	-1.787	
	Count of living hyaline foraminifers				
80.37	(Sediment organic carbon)^2	0.5879	+1895.7		
83.47	Percent clay	4.851	+1555.1	-2.622	

(Continued on next page)

Appendix VII-a. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Log_{10} (Count of living benthic foraminifers)				
51.77	(Sediment total carbon)^2	1.1998	+49.211		
57.54	(Percent sand)^2	-2.0805	+38.454	+0.00034	
	Log_{10} (Count of living agglutinated foraminifers)				
30.07	(Sediment total carbon)^2	1.2065	+31.307		
33.22	(Average grain size, ϕ)^2	1.5027	+24.118	-0.0693	
	Log_{10} (Count of living hyaline foraminifers)				
77.63	(Sediment total carbon)^2	-0.0329	+121.23		
84.80	(Percent sand)^2	-7.3964	+97.087	+0.00077	
	Decimal fraction, living agglutinated foraminifers				
75.99	(Sediment total carbon)^2	0.9908	-31.285		
85.60	Percent clay	0.8851	-23.797	+0.0582	
	Decimal fraction, living hyaline foraminifers				
75.99	(Sediment total carbon)^2	0.0092	+31.285		
85.60	(Percent clay)	0.1149	+23.797	-0.0582	

(Continued on next page)

Appendix VII-a. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Hyaline/agglutinated ratio				
73.39	(Sediment organic carbon)^2	0.0852	+46.358		
80.63	Sediment organic nitrogen	0.0361	+46.871	+1.151	
	Diversity (Simpson), living benthic foraminifers				
35.67	Water oxygen	0.8544	-0.0395		
41.60	(Sediment organic carbon)^2	0.7756	-0.029	+7.393	
	Diversity (Shannon), living benthic foraminifers				
85.36	Fraction agglutinated	-0.29655	+2.664		
94.90	Hyaline count	0.02406	+2.010	-0.0143	
96.22	Month of cruise	0.01892	+2.087	+0.018	-0.0143

Appendix VII-b. Results from seasonal station SG-15. Data from 10 samples.

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Count of living benthic foraminifers				
39.69	Depth (meters)	3054.3	-29.167		
66.50	$(\text{Percent carbonate})^2$	3728.3	-35.36	-79936.	
78.05	Water nitrate	4170.9	-39.37	-88681.	-1.669
	Count of living agglutinated benthic foraminifers				
54.39	Water oxygen	82.391	-16.373		
73.50	Month of cruise	46.31	-15.42	+4.372	
80.38	Depth (meters)	659.37	-14.31	+3.363	-6.015
	Count of living hyaline benthic foraminifers				
48.99	Percent silt	22.905	+2.133		
67.49	$(\text{Temperature})^2$	-149.77	+3.472	+2.296	
68.34	Month of cruise	-208.98	+4.046	+3.486	-3.622
	Log_{10} (Count of living benthic foraminifers)				
42.21	Depth (meters)	15.051	-0.1296		
66.12	$(\text{Percent carbonate})^2$	17.794	-0.1548	- 32.53	
84.05	Median grain size, ϕ	30.114	-0.261	-976.7	-0.396

(Continued on next page)

Appendix VII-b. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Log_{10} (Count of living agglutinated foraminifers)				
41.28	Water oxygen	1.8805	-0.1279		
73.70	Month of cruise	1.459	-0.1168	+0.0511	
84.59	Water nitrate	1.2066	-0.164	+0.073	+0.0093
	Log_{10} (Count of living hyaline benthic foraminifers)				
41.16	Depth (meters)	15.904	-0.14084		
70.40	Percent carbonate	18.6995	-0.1661	-11.956	
78.37	$(\text{Water nitrate})^2$	21.214	-0.1892	-14.81	-0.00023
	Decimal fraction, living agglutinated foraminifers				
33.63	$(\text{Water nitrate})^2$	0.5372	-0.00013		
38.69	Month of cruise	0.6249	-0.00017	-0.0089	
	Decimal fraction, living hyaline foraminifers				
34.10	$(\text{Water nitrate})^2$	0.4624	+0.00013		
38.67	Month of cruise	0.3804	+0.00016	+0.0084	

(Continued on next page)

Appendix VII-b. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i)		
			1	2	3
	Hyaline/agglutinated ratio				
38.18	(Percent silt)^2	1.0363	+0.00046		
44.36	(Water oxygen)^2	0.8183	-0.00054	-0.031	
	Diversity (Simpson), living benthic foraminifers				
68.19	(Depth in meters)^2	1.795	-0.000088		
82.91	Hyaline count	2.097	-0.00012	-0.00032	
85.75	(Water oxygen)^2	2.1707	-0.00012	-0.00039	-0.001
	Diversity (Shannon), living benthic foraminifers				
94.80	(Depth in meters)^2	12.712	-0.00098		
96.31	(Water phosphate)^2	12.000	-0.00092	+0.0148	
98.67	Fraction hyaline	9.621	-0.00083	+0.0232	+1.57
99.36	Agglutinated count	9.182	-0.00078	+0.0235	+1.422
			+0.00099		

Appendix VII-c. Results from seasonal station SG-2. Data from 13 samples.

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Count of living benthic foraminifers				
79.01	(Percent sand)^2	-198.2	+0.0555		
84.30	(Water phosphate)^2	-462.8	+0.0871	+17.865	
85.86	(Sediment sorting)^2	-523.9	-0.095	+12.47	+7.904
	Count of living agglutinated benthic foraminifers				
75.53	(Sediment carbonate)^2	83.955	-25378.		
85.74	Month of cruise	45.13	-16097.	+3.299	
88.35	Water oxygen	70.689	-15895.	+2.507	-9.795
	Count of living hyaline benthic foraminifers				
75.65	(Percent sand)^2	-138.52	+0.0398		
80.53	(Sediment sorting)^2	-298.1	+0.0597	+8.938	
81.20	Month of cruise	-287.3	+0.017	+5.844	+2.72
	Log_{10} (Count of living benthic foraminifers)				
80.19	(Percent sand)^2	0.9576	+0.000177		
89.22	Month of cruise	1.129	+0.0001	+0.04333	
93.39	(Water oxygen)^2	1.609	+0.00007	+0.0402	-0.044

(Continued on next page)

Appendix VII-c. (Continued)

R^2	Dependent variable (Y) Independent variable (X_i)	Constant	Step (i) 1	2	3
	Log_{10} (Count of living agglutinated foraminifers)				
74.53	Month of cruise	0.8098	+0.0942		
81.81	(Percent silt)^2	1.223	+0.068	-0.0012	
82.02	(Water oxygen)^2	1.265	+0.066	-0.0011	-0.012
	Log_{10} (Count of living hyaline foraminifers)				
77.49	(Percent sand)^2	0.8713	+0.00017		
85.48	(Water oxygen)^2	1.536	+0.00011	-0.05895	
91.08	Month of cruise	1.61	+0.00006	-0.054	+0.0336
	Decimal fraction, living agglutinated foraminifers				
21.52	(Sediment organic nitrogen)^2	0.277	-0.0005		
27.52	(Sediment carbonate)^2	0.247	-0.0009	+33.66	
30.62	Water phosphate	0.238	-0.0014	+75.606	-0.0203
	Decimal fraction, living hyaline foraminifers				
35.99	(Sediment organic nitrogen)^2	0.692	+0.0007		
39.16	(Water nitrate)^2	0.713	+0.00115	-0.00008	

(Continued on next page)

Appendix VII-c. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Hyaline /agglutinated ratio				
20.85	(Sediment organic nitrogen)^2	2.506	+0.0152		
27.91	(Water nitrate)^2	3.39	+0.0336	-0.0034	
	Diversity (Simpson), living benthic foraminifers				
46.08	Month of cruise	0.639	+0.0183		
78.72	(Sediment sorting)^2	0.4769	+0.033	+0.0182	
80.96	Count agglutinated	0.4865	+0.0382	+0.0168	-0.0011
	Diversity (Shannon), living benthic foraminifers				
83.76	Hyaline /agglutinated	-1.554	+4.748		
95.74	Month of cruise	-0.77	+3.202	+0.0612	
97.03	Agglutinated/living	-4.746	+3.126	+0.0559	+4.127

Appendix VII-d. Results from seasonal station SG-8. Data from 13 samples.

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Count of living benthic foraminifers				
22.72	(Water phosphate)^2	645.73	-44.64		
34.18	Sediment total carbon	1598.3	-61.93	-460.3	
43.14	Depth (meters)	3578.4	-59.52	-542.3	-9.192
	Count of living agglutinated benthic foraminifers				
18.44	Median grain size, ϕ	112.3	- 8.875		
38.19	(Sediment organic carbon)^2	237.0	-14.66	-32.596	
46.42	(Depth in meters)^2	411.6	-14.07	-36.04	-413.
	Count of living hyaline benthic foraminifers				
25.27	(Water phosphate)^2	533.6	-38.99		
36.79	(Sediment total carbon)^2	986.3	-53.04	-107.6	
44.75	Depth (meters)	2472.7	-51.05	-125.2	-7.171
	Log_{10} (Count of living benthic foraminifers)				
30.53	(Median grain size, ϕ)^2	2.73	-0.011		
61.75	Water oxygen	2.789	-0.0316	+0.325	
70.31	Salinity	3.111	-0.0338	+0.352	-0.0098

(Continued on next page)

Appendix VII-d. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Log_{10} (Count of agglutinated living foraminifers)				
27.81	(Median grain size, ϕ)^2	2.8258	-0.00919		
47.02	(Sediment organic carbon)^2	2.730	-0.0134	-0.198	
52.44	Salinity	2.847	-0.0131	-0.167	-0.007
	Log_{10} (Count of living hyaline foraminifers)				
33.63	Water phosphate	3.441	-0.434		
57.41	(Average grain size, ϕ)^2	4.657	-0.5896	-0.0175	
66.04	(Depth in meters)^2	6.129	-0.567	-0.0204	-0.00003
	Decimal fraction, living agglutinated foraminifers				
34.51	(Water phosphate)^2	0.08895	+0.0195		
45.54	(Sediment organic carbon)^2	-0.065	+0.024	+0.0418	
47.80	Salinity	-0.0297	+0.023	+0.046	-0.0014
	Decimal fraction, living hyaline foraminifers				
26.84	(Water phosphate)^2	0.888	-0.01789		
42.96	(Sediment organic carbon)^2	1.082	-0.0234	-0.0526	
45.56	(Salinity)^2	1.043	-0.0227	-0.057	+0.00004

(Continued on next page)

Appendix VII-d. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step (i) 1	2	3
	Hyaline /agglutinated ratio				
37.46	(Water phosphate)^2	6.336	-0.363		
53.83	Median grain size, ϕ	5.899	-0.552	+0.3584	
56.18	(Average grain size, ϕ)^2	7.263	-0.614	+0.398	-0.0024
	Diversity (Simpson), living benthic foraminifers				
65.39	Count hyaline	0.915	-0.00032		
79.38	Count agglutinated	0.889	-0.0006	+0.00135	
85.14	(Water phosphate)^2	0.968	-0.0007	+0.0017	-0.0094
	Diversity (Shannon), living benthic foraminifers				
85.76	Fraction hyaline	0.05667	+2.833		
93.76	(Water oxygen)^2	0.172	+2.856	-0.0044	
96.50	(Sediment percent carbonate)^2	0.1503	+3.043	-0.00999	+50.022

Appendix VII-e. Results from seasonal stations SG-6 and -8. Data from 20 samples.

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step 1	Step 2	Step 3	Step 4
	Count of living benthic foraminifers					
12.40	Median grain size, φ	480.88	- 42.51			
28.88	Month of cruise	828.73	- 73.877	-25.384		
43.73	Percent sand	945.19	- 94.286	-43.394	+18.411	
47.96	(Sediment sorting)^2	1412.99	-111.42	-56.899	+12.87	-42.96
	Count of living agglutinated benthic foraminifers					
15.97	Median grain size, φ	110.68	- 8.953			
33.32	Sediment organic carbon	297.55	-13.53	- 95.83		
43.79	(Sediment organic nitrogen)^2	338.67	-21.46	-109.48	+0.129	
46.92	Salinity	347.42	-21.25	- 98.50	+0.129	-0.89
	Count of living hyaline benthic foraminifers					
11.96	Depth (meters)	-195.48	+2.1094			
22.07	(Percent carbonate)^2	- 93.36	+2.267	- 4.267		
39.39	(Water oxygen)^2	- 18.09	+2.775	- 8.841	+30.31	
54.16	Sediment organic nitrogen	- 30.28	+2.209	-17.49	+42.14	+14.50

(Continued on next page)

Appendix VII-e. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step 1	Step 2	Step 3	Step 4
	Log_{10} (Count of living benthic foraminifers)					
20.81	Median grain size, ϕ	2.7398	-0.0813			
39.78	Sediment organic carbon	4.294	-0.119	-0.7972		
54.55	Month of cruise	4.888	-0.166	-0.852	-0.0356	
60.45	(Salinity)^2	5.084	-0.17	-0.739	-0.0419	-0.0003
	Log_{10} (Count of living agglutinated foraminifers)					
21.21	(Median grain size)^2	2.012	-0.009			
36.11	Sediment organic carbon	3.0756	-0.01217	-0.157		
49.06	(Sediment organic nitrogen)^2	3.333	-0.0215	-0.67	+0.0011	
54.46	Salinity	3.429	-0.0216	-0.582	+0.0011	-0.0077
	Log_{10} (Count of living hyaline foraminifers)					
21.03	Temperature	1.4939	+0.0818			
36.55	Sediment organic carbon	2.6033	+0.109	-0.782		
52.72	(Month of cruise)^2	2.479	+0.168	-0.861	-0.0035	
66.22	Sediment percent clay	1.662	+0.245	+0.100	-0.0095	-0.0392

(Continued on next page)

Appendix VII-e. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step 1	Step 2	Step 3	Step 4
	Decimal fraction, living agglutinated foraminifers					
41.08	Depth (meters)	0.6987	-0.0023			
47.69	Temperature	0.7558	-0.002	-0.0142		
58.62	(Water oxygen)^2	0.867	-0.0019	-0.0225	-0.0119	
63.66	(Median grain size)^2	0.666	-0.003	+0.0068	-0.019	+0.0054
	Decimal fraction, living hyaline foraminifers					
38.49	Depth (meters)	0.3082	+0.0022			
45.39	(Water oxygen)^2	0.2526	+0.0023	+0.0086		
61.34	(Median grain size)^2	0.2792	+0.0026	+0.0192	-0.004	
63.50	Sediment organic nitrogen	0.3125	+0.0024	+0.0218	-0.0059	+0.0032
	Hyaline/agglutinated ratio					
33.20	Depth (meters)	-2.760	+0.0312			
45.29	(Water silicate)^2	-3.494	+0.0391	-0.00045		
58.86	(Water oxygen)^2	-4.851	+0.0427	-0.0005	+0.1872	
65.41	(Median grain size)^2	-4.2388	+0.0428	-0.0004	+0.292	-0.0434

(Continued on next page)

Appendix VII-e. (Continued)

R^2	Dependent variable (Y) / Independent variable (X_i)	Constant	Step 1	Step 2	Step 3	Step 4
	Diversity (Simpson), living benthic foraminifers					
70.29	Hyaline count	0.93166	-0.000357			
81.62	Agglutinated count	0.8993	-0.0006	+0.00113		
85.47	(Median grain size, ϕ)^2	0.9466	-0.0006	+0.0009	-0.0012	
88.85	Water oxygen	0.9515	-0.0006	+0.00095	-0.0027	+0.023
90.52	Salinity	1.0071	-0.0006	+0.00077	-0.0031	+0.0267
			-0.00133			
	Diversity (Shannon), living benthic foraminifers					
85.11	Fraction hyaline	-0.1696	+3.1199			
90.85	(Sediment organic nitrogen)^2	+0.01121	+3.014	-0.00047		
93.59	Hyaline count	+0.89025	+3.914	-0.000373	+0.00048	
94.38	(Water phosphate)^2	+0.7214	+3.78	-0.00037	+0.00043	-0.00675

APPENDIX VIII

FORAMINIFERAL SPECIES ECOLOGIC DATA

Ecologic data description for Saccammina difflugiformis arenulata. Data for 274 specimens from 55 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	161.192	109.029	115.082
Temperature (°C)	8.108	1.935	8.344
Salinity (‰)	33.7183	0.3649	33.5949
Water phosphate	2.300	1.006	1.987
Water silicate	36.891	17.406	32.201
Water nitrate	22.187	11.718	18.784
Water oxygen	2.338	1.183	2.739
Month of collection	7.774	3.372	7.606
Sediment median grain size, ϕ	3.263	1.452	1.888
Sediment percent carbonate	0.078	0.205	0.048
Sediment percent sand	62.831	35.419	80.551
Sediment percent silt	25.707	25.595	13.393
Sediment percent clay	11.461	10.619	6.057
Sediment sorting	1.783	1.049	1.119
Sediment average grain size, ϕ	3.816	1.879	2.808
Sediment total carbon	0.675	0.698	0.388
Sediment organic carbon	0.638	0.671	0.368
Sediment organic nitrogen	3.674	5.825	1.784
Specimen count/sample	5.170	6.351	
Specimen percent/sample	9.561	16.400	

Ecologic data description for Thalmanammina parkerae. Data for 407 specimens from 65 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	162.351	80.413	150.186
Temperature (°C)	8.098	1.855	9.079
Salinity (‰)	33.7719	0.2647	33.7540
Water phosphate	2.281	1.125	1.939
Water silicate	36.559	18.749	31.510
Water nitrate	20.979	12.661	17.033
Water oxygen	2.065	0.976	1.914
Month of collection	7.954	3.204	9.138
Sediment median grain size, ϕ	3.741	1.408	3.628
Sediment percent carbonate	0.104	0.224	0.072
Sediment percent sand	54.127	35.379	53.839
Sediment percent silt	31.468	25.303	32.258
Sediment percent clay	14.404	10.835	13.903
Sediment sorting	2.030	0.926	2.051
Sediment average grain size, ϕ	4.446	1.757	4.448
Sediment total carbon	0.885	0.717	0.786
Sediment organic carbon	0.805	0.692	0.738
Sediment organic nitrogen	4.332	6.293	3.085
Specimen count/sample	6.263	7.174	
Specimen percent/sample	3.481	2.956	

Ecologic data description for Cribrostomoides columbiensis. Data for 286 specimens from 62 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	144.398	41.049	151.226
Temperature (°C)	8.220	1.771	8.863
Salinity (‰)	33.7716	0.2720	33.7855
Water phosphate	2.162	1.191	1.928
Water silicate	34.961	18.648	37.424
Water nitrate	20.149	13.364	23.366
Water oxygen	2.077	0.9378	1.932
Month of collection	7.864	3.170	7.101
Sediment median grain size, ϕ	3.691	1.310	3.226
Sediment percent carbonate	0.1433	0.0294	0.3388
Sediment percent sand	56.914	35.750	60.878
Sediment percent silt	29.457	25.542	26.020
Sediment percent clay	13.629	10.973	13.100
Sediment sorting	1.9298	0.9965	2.3089
Sediment average grain size, ϕ	4.365	1.752	3.897
Sediment total carbon	0.8946	0.7322	0.8072
Sediment organic carbon	0.7503	0.7132	0.6347
Sediment organic nitrogen	4.612	6.394	4.336
Specimen count/sample	4.847	7.728	
Specimen percent/sample	2.855	2.961	

Ecologic data description for Textularia sandiegoensis. Data for 188 specimens from 46 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	166.035	59.234	179.976
Temperature (°C)	7.948	1.754	8.013
Salinity (‰)	33.8155	0.2942	33.7371
Water phosphate	2.157	1.214	1.659
Water silicate	37.978	19.290	33.167
Water nitrate	20.934	14.344	18.480
Water oxygen	1.748	0.972	1.542
Month of collection	7.721	3.104	8.207
Sediment median grain size, ϕ	4.005	1.527	3.869
Sediment percent carbonate	0.138	0.269	0.107
Sediment percent sand	49.282	39.766	53.863
Sediment percent silt	34.449	28.170	31.243
Sediment percent clay	16.269	12.436	14.890
Sediment sorting	2.015	1.028	1.707
Sediment average grain size, ϕ	4.645	2.035	4.543
Sediment total carbon	0.983	0.805	1.109
Sediment organic carbon	0.869	0.791	0.942
Sediment organic nitrogen	5.352	7.048	5.102
Specimen count/sample	4.372	4.359	
Specimen percent/sample	2.482	1.988	

Ecologic data description for Eggerella advena. Data for 702 specimens from 76 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	154.707	83.541	149.369
Temperature (°C)	8.124	1.799	8.009
Salinity (‰)	33.7463	0.34067	33.8216
Water phosphate	2.244	1.096	2.118
Water silicate	36.329	18.179	36.561
Water nitrate	20.520	13.087	20.488
Water oxygen	2.195	1.185	1.958
Month of collection	7.630	3.364	7.809
Sediment median grain size, ϕ	3.569	1.524	4.091
Sediment percent carbonate	0.107	0.242	0.071
Sediment percent sand	58.690	37.206	45.807
Sediment percent silt	28.089	26.398	38.467
Sediment percent clay	13.220	11.528	15.725
Sediment sorting	1.833	1.031	1.805
Sediment average grain size, ϕ	4.172	1.918	4.727
Sediment total carbon	0.832	0.743	1.009
Sediment organic carbon	0.737	0.712	0.947
Sediment organic nitrogen	4.188	6.333	5.823
Specimen count/sample	9.616	10.700	
Specimen percent/sample	7.948	8.624	

Ecologic data description for Brizalina pacifica. Data for 3058 specimens from 79 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	171.86	94.72	165.96
Temperature (^{o}C)	7.955	1.820	8.310
Salinity (‰)	33.7885	0.2538	33.7198
Water phosphate	2.273	1.081	2.016
Water silicate	36.394	16.196	33.236
Water nitrate	21.348	12.451	18.220
Water oxygen	2.101	0.935	1.781
Month of collection	7.671	3.296	8.030
Sediment median grain size, ϕ	3.596	1.474	3.654
Sediment percent carbonate	0.134	0.279	0.219
Sediment percent sand	57.468	35.131	52.070
Sediment percent silt	28.665	25.143	32.689
Sediment percent clay	13.865	10.796	15.239
Sediment sorting	2.106	1.024	2.074
Sediment average grain size, ϕ	4.203	1.863	4.555
Sediment total carbon	0.872	0.7133	1.114
Sediment organic carbon	0.753	0.6897	0.888
Sediment organic nitrogen	4.532	6.255	4.520
Specimen count/sample	40.237	43.869	
Specimen percent/sample	21.108	16.084	

Ecologic data description for Globobulimina auriculata. Data for 248 specimens from 50 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	140.6	41.2	131.3
Temperature (°C)	8.43	1.99	8.89
Salinity (‰)	33.725	0.332	33.792
Water phosphate	2.25	1.17	2.52
Water silicate	36.6	17.10	36.5
Water nitrate	21.52	12.26	20.98
Water oxygen	2.29	1.04	2.45
Month of collection	7.66	3.36	8.57
Sediment median grain size, ϕ	3.54	1.11	3.65
Sediment percent carbonate	0.156	0.327	0.135
Sediment percent sand	58.15	32.03	58.10
Sediment percent silt	28.92	23.22	29.69
Sediment percent clay	12.93	9.54	12.21
Sediment sorting	2.003	0.982	2.061
Sediment average grain size, ϕ	4.293	1.590	4.306
Sediment total carbon	0.836	0.684	0.707
Sediment organic carbon	0.665	0.656	0.534
Sediment organic nitrogen	4.348	6.046	3.501
Specimen count/sample	2.043	1.062	
Specimen percent/sample	5.139	4.288	

Ecologic data description for <u>Uvigerina juncea</u>. Data for 838 specimens from 70 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	170.9	86.2	166.3
Temperature (°C)	7.97	1.87	8.83
Salinity (‰)	33.805	0.244	33.705
Water phosphate	2.30	1.12	2.02
Water silicate	37.3	17.13	31.71
Water nitrate	21.47	12.64	18.88
Water oxygen	2.07	0.95	1.84
Month of collection	7.30	3.36	8.10
Sediment median grain size, φ	3.78	1.47	4.04
Sediment percent carbonate	0.132	0.278	0.087
Sediment percent sand	53.00	34.92	39.14
Sediment percent silt	31.94	24.97	42.30
Sediment percent clay	15.06	10.81	18.56
Sediment sorting	2.146	0.904	2.140
Sediment average grain size, φ	4.486	1.795	5.191
Sediment total carbon	0.951	0.699	1.177
Sediment organic carbon	0.839	0.684	1.090
Sediment organic nitrogen	5.048	6.457	5.695
Specimen count/sample	12.507	11.877	
Specimen percent/sample	6.551	4.276	

Ecologic data description for Epistominella exigua. Data for 1398 specimens from 67 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	167.8	86.5	183.9
Temperature (°C)	7.93	1.81	6.15
Salinity (‰)	33.791	0.258	33.793
Water phosphate	2.24	1.12	2.17
Water silicate	37.1	18.76	32.07
Water nitrate	20.48	13.07	20.95
Water oxygen	2.05	0.96	2.27
Month of collection	7.84	3.11	5.27
Sediment median grain size, ϕ	3.69	1.51	5.13
Sediment percent carbonate	0.133	0.278	0.093
Sediment percent sand	55.63	36.76	22.71
Sediment percent silt	30.22	26.13	52.57
Sediment percent clay	14.15	11.40	24.86
Sediment sorting	1.964	0.952	2.292
Sediment average grain size, ϕ	4.347	1.860	6.014
Sediment total carbon	0.913	0.736	1.473
Sediment organic carbon	0.778	0.716	1.346
Sediment organic nitrogen	4.503	6.504	10.506
Specimen count/sample	20.731	64.159	
Specimen percent/sample	8.178	9.065	

Ecologic data description for *Florilus scaphus basispinatus*. Data for 709 specimens from 67 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	159.251	82.034	137.435
Temperature (°C)	8.095	1.878	8.414
Salinity (‰)	33.7982	0.2407	33.8031
Water phosphate	2.234	1.162	2.556
Water silicate	37.236	18.088	40.218
Water nitrate	20.788	12.991	22.124
Water oxygen	2.007	0.935	2.030
Month of collection	7.908	3.181	7.983
Sediment median grain size, ϕ	3.736	1.498	3.505
Sediment percent carbonate	0.133	0.282	0.117
Sediment percent sand	53.921	36.660	58.696
Sediment percent silt	31.531	26.034	28.503
Sediment percent clay	14.548	11.385	13.773
Sediment sorting	2.042	0.956	2.130
Sediment average grain size, ϕ	4.363	1.913	4.223
Sediment total carbon	0.886	0.749	0.748
Sediment organic carbon	0.775	0.716	0.646
Sediment organic nitrogen	4.392	6.473	3.729
Specimen count/sample	10.908	11.223	
Specimen percent/sample	7.346	7.923	

Ecologic data description for <u>Nonionella stella</u>. Data for 564 specimens from 68 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	148.017	67.530	145.254
Temperature (°C)	8.208	1.819	9.270
Salinity (‰)	33.7833	24.9036	33.7083
Water phosphate	2.210	1.156	2.214
Water silicate	35.818	17.984	33.860
Water nitrate	20.354	13.132	21.167
Water oxygen	2.093	0.994	2.153
Month of collection	7.862	3.245	8.472
Sediment median grain size, ϕ	3.733	1.502	3.914
Sediment percent carbonate	0.145	0.306	0.086
Sediment percent sand	54.358	36.583	43.622
Sediment percent silt	31.415	26.045	39.261
Sediment percent clay	14.226	11.407	17.115
Sediment sorting	1.992	0.957	2.154
Sediment average grain size, ϕ	4.350	1.898	4.950
Sediment total carbon	0.909	0.729	0.953
Sediment organic carbon	0.771	0.709	0.858
Sediment organic nitrogen	4.351	6.364	4.446
Specimen count/sample	8.677	9.708	
Specimen percent/sample	4.837	4.267	

Ecologic data description for Nonionella turgida digitata. Data for 359 specimens from 56 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	164.398	78.494	144.569
Temperature (°C)	8.130	1.942	8.345
Salinity (‰)	33.8098	0.2345	33.7839
Water phosphate	2.244	1.190	2.467
Water silicate	36.817	18.178	31.555
Water nitrate	20.383	13.346	17.748
Water oxygen	1.997	0.989	2.072
Month of collection	7.923	3.229	
Sediment median grain size, ϕ	3.901	1.427	4.115
Sediment percent carbonate	0.130	0.282	0.125
Sediment percent sand	50.878	34.533	43.657
Sediment percent silt	33.763	24.817	39.353
Sediment percent clay	15.358	10.595	16.989
Sediment sorting	2.166	0.873	2.206
Sediment average grain size, ϕ	4.580	1.759	
Sediment total carbon	0.964	0.702	0.970
Sediment organic carbon	0.832	0.693	0.818
Sediment organic nitrogen	4.592	6.431	4.348
Specimen count/sample	6.904	6.219	
Specimen percent/sample	4.010	3.679	

Ecologic data description for Nonionellina labradorica. Data for 386 specimens from 43 samples.

Variable	Average	Standard deviation	Weighted average
Depth in meters	146.479	64.160	128.575
Temperature (°C)	8.642	2.045	9.327
Salinity (‰)	35.199	9.203	33.743
Water phosphate	4.153	10.235	2.863
Water silicate	33.737	19.084	35.179
Water nitrate	17.157	13.899	20.681
Water oxygen	1.888	1.102	2.218
Month of collection	8.452	3.117	9.031
Sediment median grain size, ϕ	4.034	1.479	3.933
Sediment percent carbonate	0.710	3.941	0.071
Sediment percent sand	41.961	32.978	44.641
Sediment percent silt	39.526	24.516	38.957
Sediment percent clay	17.817	9.880	16.401
Sediment sorting	2.276	0.728	2.300
Sediment average grain size, ϕ	4.914	1.801	4.950
Sediment total carbon	0.986	0.774	0.906
Sediment organic carbon	1.275	2.397	0.836
Sediment organic nitrogen	4.946	8.872	2.729
Specimen count/sample	9.190	11.221	
Specimen percent/sample	5.140	5.011	

APPENDIX IX

RESULTS OF REGRESSION ANALYSIS OF FORAMINIFERAL SPECIES ABUNDANCE

The regression is terminated at the minimum value of the standard deviation of Y, which is the best fit of the regression surfaces to the data. Coefficients of X_i which are not significantly different than zero are underlined. Percent abundance is actually the decimal fraction.

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of *Saccammina difflugiformis arenulata*		
0	32.1306		
1		[deleted]	27.61
2		[deleted]	34.78
3	- <u>0.0663</u>	Water silicate	37.60
4	- 7.0009	Average grain size, ϕ	39.27
5	- 0.0379	Depth in meters	44.24
6		[delete step 2]	
7	+ 0.0104	(Sediment percent clay)^2	51.48
8	-24.6177	Sediment percent carbonate	54.74
9		[delete step 1]	
10	+ 0.0023	(Sediment percent silt)^2	61.37
11	+ <u>0.7503</u>	(Sediment sorting)^2	63.17
12	+ <u>2.2116</u>	Sediment total carbon	64.16

(Continued on next page)

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Percent of *S. difflugiformis arenulata*		
0	- 1.9692		
1	+ 0.000032	(Sediment percent sand)^2	35.60
2	+ 0.0154	(Water oxygen)^2	52.26
3	+ 0.000036	(Sediment percent silt)^2	62.98
4	- 0.00075	Depth in meters	65.57
5	- 0.00141	Water nitrate	67.55
6	+ 0.000007	(Water silicate)^2	69.24
7	+ 0.01185	Sediment percent clay	71.18
8	- 0.2274	Sediment percent carbonate	72.22
9	- 0.096	Sediment median grain size, ϕ	74.22
10	+ 0.00191	(Salinity)^2	76.31
11	- 0.00152	(Temperature)^2	76.88
12	- 0.00069	(Month of collection)^2	77.48
13	- 0.00348	(Water phosphate)^2	78.11

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of *Thalmanammina parkerae*		
0	-343.8762		
1	+ 0.1345	$(\text{Temperature})^2$	21.98
2		[deleted]	27.64
3	+ 10.2575	Salinity	34.88
4	- 2.0269	$(\text{Sediment total carbon})^2$	38.31
5	- 0.7753	$(\text{Water oxygen})^2$	40.72
6	+ 0.0187	$(\text{Sediment organic nitrogen})^2$	43.58
7	- 0.04035	$(\text{Month of collection})^2$	45.17
8	- 0.00175	$(\text{Water silicate})^2$	46.94
9		[delete step 2]	
	Percent of *T. parkerae*		
0	- 1.8783		
1	+ 0.00632	Temperature	11.15
2	+ 0.05702	Salinity	16.91
3	- 0.000027	$(\text{Water nitrate})^2$	22.88
4		[deleted]	30.17
5	- 0.04204	Sediment percent carbonate	33.98
6	- 0.000099	Depth in meters	36.13
7	- 0.00731	Average grain size, ϕ	38.43
8		[delete step 4]	

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of *Cribrostomoides columbiensis*		
0	19.583		
1	+26.095	Sediment percent carbonate	18.05
2	- 0.3285	(Water phosphate)^2	25.40
3		[deleted]	35.34
4	- 1.8087	Sediment sorting	41.87
5	- 0.0047	(Water silicate)^2	43.96
6		[deleted]	45.65
7		[deleted]	46.60
8	+ 0.0162	(Water nitrate)^2	49.41
9	- 4.9224	Water oxygen	50.39
10		[delete step 6]	
11	- 2.733	(Sediment total carbon)^2	52.45
12		[delete step 7]	
13	- 0.00104	(Sediment percent sand)^2	54.36
14		[delete step 3]	
15	- 0.0239	Depth in meters	55.32
	Percent of *C. columbiensis*		
0	0.08131		
1	- 0.000274	(Month of collection)^2	14.09
2	- 0.00989	Median grain size, ϕ	26.16
3	- 0.00201	(Water phosphate)^2	30.99
4	- 0.02161	Sediment percent carbonate	33.38
5	+ 0.000013	(Water nitrate)^2	35.59
6	- 0.000003	(Sediment percent silt)^2	36.94

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of *Eggerella advena*		
0	-43.8196		
1	+ 0.00744	(Sediment percent silt)^2	17.32
2	- 1.05587	Sediment percent clay	27.85
3	+ 0.04621	(Salinity)^2	32.07
4	+ 0.04621	(Organic nitrogen)^2	33.71
5	- 4.7572	Sediment total carbon	35.98
6	- 2.6048	Water oxygen	37.86
7	+ 1.559	Temperature	38.86
8	+ 0.428	(Water phosphate)^2	40.21
9	- 0.5631	Month of collection	41.28
	Percent of *E. advena*		
0	- 2.38 95		
1	- 0.0563	Sediment sorting	19.51
2	+ 0.002473	(Salinity)^2	25.96
3	- 0.000223	Depth in meters	28.66
4	+ 0.000123	(Sediment percent clay)^2	31.21
5	- 0.04651	Median grain size, ϕ	40.33
6	+ 0.000033	(Sediment percent silt)^2	45.95
7	- 0.03633	Sediment total carbon	51.75
8	- 0.000774	(Month of collection)^2	54.28
9	- 0.004754	Sediment organic nitrogen	56.43
10	- 0.07778	Sediment percent carbonate	58.88
11	- 0.00003	(Water nitrate)^2	60.40

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of Textularia sandiegoensis		
0	133.3155		
1	- 0.5963	(Water phosphate)^2	19.44
2	- 0.1049	(Water oxygen)^2	24.16
3		[deleted]	27.76
4	- 0.10665	(Salinity)^2	30.19
5	- 0.077	(Temperature)^2	35.43
6	+ 1.945	Sediment total carbon	36.43
7	- 0.001888	(Sediment percent silt)^2	42.46
8		[delete step 3]	
9	+ 1.531	Average grain size, ϕ	46.03
10	- 0.00894	(Sediment organic nitrogen)^2	47.97
	Percent of T. sandiegoensis		
0	0.01155		
1	+ 1.2304	Depth in meters	23.68
2	- 0.00036	(Temperature)^2	32.85
3	- 0.002073	(Water phosphate)^2	37.46
4	- 0.0000133	(Sediment percent silt)^2	40.67
5	+ 0.009477	Average grain size, ϕ	53.97
6	+ 0.007897	(Sediment organic carbon)^2	57.01
7	- 0.000055	(Sediment organic nitrogen)^2	59.17
8	+ 0.00023	Water nitrate	61.12

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of Brizalina pacifica		
0	4316.59		
1		[deleted]	10.63
2		[deleted]	22.44
3		[deleted]	26.96
4	- 13.507	$(\text{Water oxygen})^2$	31.58
5		[deleted]	33.85
6	+ 54.792	Sediment percent carbonate	37.20
7	- 27.672	Average grain size, ϕ	41.66
8	- 127.755	Salinity	43.96
9	+ 87.7576	Sediment total carbon	46.22
10	+ 0.1002	$(\text{Water nitrate})^2$	47.89
11		[delete step 3]	
12		[deleted]	50.38
13	- 4.963	Water silicate	51.50
14		[delete step 2]	
15	- 67.259	Sediment organic carbon	53.12
16	+ 1.33	$(\text{Temperature})^2$	55.37
17	+ 0.2363	Depth in meters	57.30
18		[delete step 12]	
19	+ 44.859	Median grain size, ϕ	59.74
20	+ 0.05186	$(\text{Water silicate})^2$	61.65
21		[delete step 5]	
22	- 7.103	Month of collection	63.72
23	- 0.0631	$(\text{Sediment percent clay})^2$	65.10
24		[deleted]	65.96
25		[delete step 24]	

(Continued on next page)

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Percent of B. pacifica		
0	-0.2383		
1	+0.32573	Sediment total carbon	12.25
2	-0.000098	(Sediment percent silt)^2	28.24
3		[deleted]	35.57
4	-0.04084	(Water phosphate)^2	39.90
5		[deleted]	44.73
6	-0.2377	Sediment organic carbon	47.79
7	+0.0726	Average grain size, ϕ	51.90
8		[deleted]	53.92
9	+0.257	Sediment percent carbonate	55.75
10	+0.00035	(Water nitrate)^2	57.84
11	-0.00694	Water silicate	60.21
12		[delete step 5]	
13	-0.00028	(Sediment percent clay)^2	62.22
14		[delete step 3]	
15	+0.1161	Water phosphate	64.78
16	-0.11734	Water oxygen	65.42
17	+0.07587	Median grain size, ϕ	66.77
18		[delete step 8]	
19	+0.000444	Depth in meters	67.97
20	+0.01959	Temperature	69.19
21	-0.001579	Sediment organic nitrogen	69.27

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of *Epistominella exigua*		
0	-34.35997		
1		[deleted]	11.60
2	+14.4392	Temperature	13.97
3	-12.0121	Month of collection	16.08
4	+ 0.2245	Depth in meters	18.00
5	+13.1792	Median grain size, ϕ	20.56
6	-18.325	Sediment sorting	23.32
7		[delete step 1]	
8	- 0.02563	$(\text{Water nitrate})^2$	24.59
9	-20.1361	$(\text{Sediment organic carbon})^2$	25.30
10	+ 0.01381	$(\text{Sediment percent silt})^2$	27.31
	Percent of *E. exigua*		
0	- 0.17527		
1	+ 0.0050	Median grain size, ϕ	34.35
2	- 0.01064	Month of collection	38.98
3	+ 0.0432	Sediment organic carbon	42.34
4	+ 0.0162	Temperature	43.95
5	+ 0.001216	Sediment percent sand	46.93
6	- 0.00019	Depth in meters	49.21

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of *Uvigerina juncea*		
0	286.1903		
1	+ 0.1962	(Temperature)^2	24.88
2	+ 0.00585	(Sediment percent silt)^2	41.69
3	+ 0.07099	(Sediment organic nitrogen)^2	45.79
4	- 0.2379	(Median grain size, ϕ)^2	54.51
5	- 0.9889	Water oxygen	58.31
6	- 0.25596	(Salinity)^2	61.50
7	- 4.1157	(Sediment organic carbon)^2	63.18
8	- 0.0013	(Sediment percent sand)^2	64.88
	Percent of *U. juncea*		
0	- 0.0097554		
1	+ 0.02872	(Sediment organic carbon)^2	18.63
2	+ 0.00034	(Temperature)^2	25.35
3	+ 0.000272	(Sediment organic nitrogen)^2	34.15
4	- 0.000046	(Sediment percent clay)^2	38.25
5	+ 0.00271	Month of collection	39.85
6	- 0.000012	(Sediment percent silt)^2	41.98
7	+ 0.01143	Average grain size, ϕ	43.61
8	- 0.0192	Sediment total carbon	44.83
9	- 0.000012	(Water nitrate)^2	45.79
10	- 0.000603	(Median grain size, ϕ)^2	46.26

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of *Florilus scaphus basispinatus*		
0	28.6085		
1	+ 1.168	(Water phosphate)^2	16.54
2	- 0.022	(Sediment percent clay)^2	23.03
3	- 0.002884	(Sediment percent sand)^2	29.99
4	- 0.00544	(Sediment percent silt)^2	36.43
5	+ 6.404	Sediment organic carbon	40.09
6	- 0.0255	Depth in meters	45.37
7	- 6.404	Water oxygen	46.32
8	- 0.0405	(Sediment organic nitrogen)^2	47.90
9	- 0.08744	(Temperature)^2	51.62
	Percent of *F. scaphus basispinatus*		
0	0.4752		
1	+ 0.00261	(Water phosphate)^2	15.41
2	+ 0.0322	(Sediment total carbon)^2	27.00
3	+ 0.0298	Sediment organic carbon	32.79
4	- 0.000322	Depth in meters	39.00
5	- 0.000051	(Sediment percent silt)^2	42.60
6	- 0.000022	(Sediment percent sand)^2	47.44
7	- 0.000143	(Sediment percent clay)^2	51.33
8	- 0.0154	Month of collection	55.62
9	- 0.14132	Sediment percent carbonate	60.37
10	- 0.005574	Sediment organic nitrogen	64.84
11	- 0.00523	Temperature	65.47

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of Nonionella stella		
0	224.821		
1	+ 0.1681	(Temperature)^2	30.15
2	+ 0.5067	Sediment organic nitrogen	38.63
3	+ 0.1251	(Water phosphate)^2	41.33
4	- 0.001238	(Sediment percent sand)^2	42.49
5	- 2.8272	(Sediment organic carbon)^2	45.70
6	- 6.5899	Salinity	47.19
	Percent of N. stella		
0	- 0.050841		
1	+ 0.0003965	(Temperature)^2	17.14
2	+ 0.009645	Water oxygen	22.87
3	- 0.04743	(Sediment percent carbonate)^2	27.45
4	- 0.000153	Depth in meters	31.16
5	+ 0.0179	Sediment sorting	32.93
6	+ 0.004246	Month of collection	33.56
7	+ 0.00179	Sediment organic nitrogen	34.77
8	- 0.01987	(Sediment orgenic carbon)^2	36.42
9	+ 0.02631	Sediment total carbon	38.35

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of *Nonionella turgida digitata*		
0	8.5363		
1	- 0.2643	Water silicate	10.75
2	+ 0.8166	(Water phosphate)^2	27.82
3	+ 0.1956	Sediment percent silt	31.80
4	- 9.559	Sediment organic carbon	43.12
5	- 1.305	Sediment sorting	48.04
6		[deleted]	49.20
7	+ 5.289	Sediment total carbon	50.27
8	+ 0.005631	(Water nitrate)^2	51.49
9	- 0.5121	(Water oxygen)^2	53.19
10	+ 0.030885	(Temperature)^2	54.09
11	- 0.002921	(Sediment percent clay)^2	54.56
12		[delete step 6]	
	Percent of *N. turgida digitata*		
0	0.2652		
1	- 0.0000116	(Sediment percent sand)^2	10.17
2	- 0.0000140	(Sediment percent clay)^2	22.69
3	- 0.0004095	Water silicate	27.28
4		[deleted]	30.84
5	- 0.00930	Median grain size	33.42
6	- 0.01123	Temperature	34.41
7	- 0.0001714	Depth in meters	36.84
8	- 0.002475	Sediment organic nitrogen	39.56
9	- 0.002938	(Sediment sorting)^2	42.75
10	+ 0.01079	Water oxygen	48.15
11		[delete step 4]	

Appendix IX. (Continued)

Step	Dependent variable (Y) Coefficient	Independent variable	R^2
	Count of *Nonionellina labradorica*		
0	5.42334		
1	+ 0.5802	$(\text{Water oxygen})^2$	8.47
2		[deleted]	12.79
3	- 0.02154	Depth in meters	15.50
4	- 0.0114	$(\text{Sediment organic nitrogen})^2$	20.40
5	- 0.007396	$(\text{Sediment percent sand})^2$	26.66
6	- 0.00942	$(\text{Sediment percent silt})^2$	28.74
7	+12.503	Sediment total carbon	35.59
8	- 0.926	Sediment percent clay	44.45
9	- 0.06183	Water silicate	45.80
10	+ 0.458	Month of collection	46.54
11		[delete step 2]	
	Percent of *N. labradorica*		
0	0.2301		
1	+ 0.003474	$(\text{Water oxygen})^2$	15.85
2	- 0.00012	Depth in meters	22.00
3	- 0.000054	$(\text{Sediment organic nitrogen})^2$	29.52
4		[deleted]	33.55
5		[deleted]	36.92
6	- 0.0000346	$(\text{Sediment percent sand})^2$	42.70
7	- 0.000053	$(\text{Sediment percent silt})^2$	47.51
8	+ 0.07652	Sediment total carbon	62.75
9		[delete step 4]	
10	- 0.00013	$(\text{Sediment percent clay})^2$	75.20
11		[delete step 5]	
12	+ 0.0004821	$(\text{Median grain size, } \phi)^2$	76.48

APPENDIX X

RESULTS OF REGRESSION ANALYSIS FOR THE ECOLOGIC CONTROL OF LIVING SPECIMEN SIZE IN MICRONS

Data taken from one core at each seasonal station.

Step	Dependent variable (Y) Independent variable	$R^2(Y)$	$R^2(Ln(Y))$
	Saccammina difflugiformis arenulata, length		
1	Median grain size, ϕ	9.12	11.91
2	$(\text{Temperature})^2$	17.63	20.96
3	Salinity	18.32	-
	$(\text{Median grain size})^2$	-	21.94
4	$(\text{Sediment percent carbonate})^2$	18.79	-
	Salinity	-	22.60
	Eggerella advena, length		
1	$(\text{Salinity})^2$	3.56	-
	Depth in meters	-	13.34
2	$(\text{Temperature})^2$	8.44	-
	$(\text{Salinity})^2$	-	17.10
3	$(\text{Depth in meters})^2$	11.83	-
	$(\text{Temperature})^2$	-	18.30
4	Temperature	14.37	20.48
	Brizalina pacifica, length		
1	$(\text{Sediment percent carbonate})^2$	7.90	-
	$(\text{Depth in meters})^2$	-	4.40
2	Month of collection	10.64	7.02

(Continued on next page)

Appendix X. (Continued)

Step	Dependent variable (Y) / Independent variable	R^2(Y)	R^2(Ln(Y))
	B. pacifica (continued)		
3	(Depth in meters)^2	12.64	-
	(Sediment percent carbonate)^2	-	9.29
4	Salinity	13.16	-
	(Median grain size, ϕ)^2	-	9.55
	Globobulimina auriculata, length		
1	(Salinity)^2	5.09	5.47
2	(Depth in meters)^2	9.86	9.57
3	(Median grain size, ϕ)^2	10.42	11.16
4	(Sediment percent carbonate)^2	10.81	-
	(Temperature)^2	-	11.49
	Uvigerina juncea, length		
1	Median grain size, ϕ	0.45	-
	Month of collection	-	0.48
2	Sediment percent carbonate	1.05	-
	Temperature	-	1.56
3	(Sediment percent carbonate)^2	2.13	-
	Median grain size, ϕ	-	2.72
	Florilus scaphus basispinatus, greater diameter		
1	Depth in meters	14.50	14.70
2	(Depth in meters)^2	25.02	26.61
3	(Temperature)^2	26.96	-
	Median grain size, ϕ	-	29.15
4	Median grain size, ϕ	27.46	-
	(Temperature)^2	-	30.49

(Continued on next page)

Appendix X. (Continued)

Step	Dependent variable (Y) Independent variable	R^2(Y)	R^2(Ln (Y))
	Nonionella stella, greater diameter		
1	Depth in meters	7.21	8.58
2	Salinity	14.55	14.84
3	$(\text{Temperature})^2$	16.39	15.83
4	$(\text{Month of collection})^2$	18.17	17.50
	Nonionella turgida digitata, greater diameter		
1	$(\text{Month of collection})^2$	5.86	-
	$(\text{Depth in meters})^2$	-	5.96
2	Salinity	12.48	-
	Month of collection	-	9.98
3	$(\text{Depth in meters})^2$	18.02	-
	Salinity	-	17.04
4	Month of collection	19.30	-
	Temperature	-	20.09