FORAMINIFERA OF THE MAFLA AREA

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ABSTRACT

The environmental monitoring program for 1975-1976 (BLM Contract No. 08550-CT5-30) was conducted along six transects running from shallow water to as deep as the 183 m contour at the edge of the Continental Shelf along the Mississipi-Alabama–Florida Shelf. Foraminiferal trends, in general, remained constant over the seasonal sampling periods. The major dominant species essentially remained the same from season to season at virtually every station with some shifts in abundance in the five or six most dominant species. The major changes in the foraminiferal faunas were in species abundance. There were minor changes in abundance from the May - June to September sampling periods. Twenty stations showed an increase in foraminiferal abundance, twenty showed a decrease and three remained essentially unchanged. There was no data for comparison at two stations due to non-collection at stations 14 and 15 during the May-June sampling period. From September to January nine stations showed an increase in foraminiferal abundance, thirty-five showed a decrease and three showed essentially no change. Seven of the nine stations showing an increase were located in Transects V and VI which were sampled immediately after Hurricane ELOISE, most of the rest showed considerable decreases in abundances of the living fauna, over 80% at some stations. The increases are probably due to increased productivity after stirring up of the bottom by the hurricane. The decreases are probably associated with adverse winter conditions.

Only three species were common to all five areas of the first year's sites; Cibicides aff. C. floridanus, Hanzawaia strattoni and Rosalina columbiensis. The second year's transects were also dominated by the same species along with an additional three species; Cassidulina curvata, Cassidulina subglobosa and Quinqueloculina lamarckiana. The additional dominant species reflect the change in the sampling program from clusters among oil lease sites to transects which run from shallower to deeper water than the depths at the first year's sampling stations.

Several trends exist among the Forminifera of the MAFLA area, some of which were noticeable In the first year's program but became more apparent with the transect method of sampling. Diversity increases seaward in almost every transect. Living percentages increase northward and to the west. Living percentages are high for areas with low sedimentation rates. The numbers of specimens increase with decreasing sediment size. The upper limit of the depth habitat for Cassidulina curvata and C. subglobosa becomes shallower to the north. The shallowest stations of Transects I, II, III and IV contain faunas with large numbers of specimens of several species attached to individual quartz grains. Some of these species, especially Asterigerina carinata and Rosalina concinna, have always been described as free-living.

In the total populations there is a relict reef fauna running in an arcuate band from offshore of Fort Myers, Florida to offshore of

Mobile, Alabama. The relict fauna is found in different depths along this band, and there is evidence that the Late Pleistocene or Early Holocene reef existed in shallower, warmer waters than are present in the same area today.

ACKNOWLEDGEMENTS

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PREVIOUS WORK

The foraminiferal faunas from the northern part of the MAFLA area are well known with several excellent papers describing ecological habitats. In 1949, S. W. Lowman reported on foraminiferal faunas from surface samples along three profiles in the northern Gulf. He also found abundant specimens of Amphistegina in an elongate band, subparallel to the shoreline, off the coast of the Florida panhandle in about 70 m of water.

The stations in MAFLA Area 5 contain faunas similar to those described by Phleger (1954) from Mississippi Sound, (1955) from the eastern Mississippi Delta area, and (1960) from the northern Gulf of Mexico, and by Lankford (1959) from the east Mississippi Delta margin. Both authors established species characteristic of ecological facies.

Parker (1954) reported on the distribution of the foraminifera in the northeastern Gulf of Mexico and found five faunal depth boundaries which she suggested were controlled by salinity and temperature. About 15 of the samples were located in the area covered by the MAFLA investigations, mostly in the northern and western part of the area, but with a few samples from the southern part of the area.

Ludwick and Walton (1957) reported on 150 benthonic foraminiferal species contained in 41 sediment samples from an area in the north-eastern Gulf of Mexico roughly covering an area. from. shore to the 183 m line, from the Mississippi Delta to Cape San Bias . They described both living and dead populations and found a nonindigenous West Indian assemblage that was abundant among the dead forms. Included were reef-type species most prominent among pinnacles on the shelf edge in 80-110 m of water.

Walton (1964), using several thousand sediment samples collected by Gulf Research and Development Company from the northeastern Gulf, east of the Mississippi Delta, made faunal analyses of the benthonic foraminiferal assemblages contained in the sediments. From this and existing data he outlined 14 biofacies based on generic dominance, and also compiled frequency distribution charts for most of the dominant species.

Research on the southern part of the MAFLA area is scarce. In addition to the few samples reported on by Parker (1954), Bandy (1956), supplementing Parker's work, reported on the foraminifera in several West Florida bays and in sediment samples from transects across the West Florida shelf. He described the ecological habitats of foraminifera the shelf. Many of the benthonic species reported by Bandy are present in the southern part of the MAFLA area..

METHODS

Duplicate sediment samples were collected from 45 stations over three sampling periods with the exception of the May-June collections from which no material was collected from stations 14 and 15 due to loss of marker buoys and insufficient time to relocate the stations.

Subsamples for foraminiferal analysis were collected in 2.5 cm diameter, 15 cm long glass tubes. The upper three cm of each subsample was extruded and preserved in glutaraldehyde to allow for identification of living specimens by protoplasm content.

After transport to the laboratory the samples were wet sieved through a 63 μm sieve to remove the finer sediment and retained wet for analysis. The retention of a wet sample allows for identification of protoplasm content without the use of questionable staining techniques. After sieving, the amount of sediment greater than 63 μm was measured, 300 specimen total populations were picked and identified, the planktonic/benthonic ratios were determined, the percentage of living specimens was determined for each sample , and the number of total and living specimens was calculated per ml of sediment and per sample. In addition, after the 300 specimen total population was picked, counts and species identifications of additional living specimens were made from each sample until a 300 specimen living population was obtained. Percentages were then determined for each species in the living populations.

<u>Results of the analyses</u>

The frequency distributions of all extant species were determined for the three sampling periods of the 1975-1976 environmental monitoring program. The six transects can be characterized by the following major dominant benthonic foraminiferal species:

Transect I

Ammonia beccarii
Asterigerina carinata
Cibicides aff. C. floridanus
Cibicides deprimus
Hanzawaia strattoni
Neoconorbina orbicularis
Quinqueloculina lamarckiana
Remaneica sp.
Rosalina concinna
Rosalina columbiensis
Rosalina foridana

Amphistegina gibbosa
Cassidulina curvata
Cassidulina subglobosa
Planulina ariminensis

Transect II

Asterigerina carinata
Cibicides aff. C. floridanus
Hanzawaia strattoni
Neoconorbina orbicularis
Quinqueloculina lamarckiana
Reussella atlantica
Rosalina columbiensis
Rosalina concinna
Textularia mayori

Cassidulina curvata
Cassidulina subglobosa
Cibicides concentricus
Planulina ariminensis
Siphonina pulchra
Trochammina advena

Transect III

Asterigerina carinata
Cibicides aff. C. floridanus
Cibicides deprimus
Hanzawaia strattoni
Planulina exorna
Quinqueloculina lamarckiana
Rosalina columbiensis
Rosalina concinna

Brizalina lowmani
Cassidulina curvata
Cassidulina subglobosa
Planulina ariminensis
Siphonina pulchra
Uvigerina flintii

Transect IV

Ammonia beccarii
Cibicides aff. C. floridanus
Elphidium discoidal
Hanzawaia strattoni
Planulina exorna
Quinqueloculina lamarckiana
Remaneica sp.
Rosalina columbiensis
Rosalina concinna

Amphistegina gibbosa
Cassidulina curvata
Cassidulina subglobosa
Cibicides concentricus
Lenticulina orbicularis
Siphonina pulchra
Uvigerina flintii

Transect V	Transect VI
Amphistegina gibbosa	Ammonia beccarii
Brizalina lowmani	Amphistegina gibbosa
Cassidulina curvata	Buliminella cf. B. bassendorfensis
Cassidulina subglobosa	Buliminella elegantissima
Cibicides aff. C. floridanus	Cassidulina curvata
Hanzawaia strattoni	Cassidulina subglobosa
Lenticulina orbicularis	Cibicides aff. C. floridanus
Nonionella atlantica	Elphidium galvestonense
Planulina exorna	Fursenkoina pontoni
Quinqueloculina lamarckiana	Hanzawaia strattoni
Reussella atlantica	Nonionella atlantica
Rosalins columbiensis	Planulina exorna
Trochammina advena	Quinqueloculina lamarckiana
----- -----	Rosalina columbiensis
Brizalina subaenariensis mexicana	Rosalina concinna
Cibicides concentricus	------
Hoeglundina elegans	Brizalina lowmani
Lenticulina calcar	Lenticulina orbicularis
Uvigerina flintii	

In general the major dominant species at almost every station remained relatively uniform throughout the three sampling seasons with only some changes in order of abundance. The species usually occurring in approximately 91 m to 183 m of water are listed below the dashed lines.

There are several general trends which are noticeable in the MAFLA area:

1) Diversity increases seaward in every transect. In general the more restricted waters of the shallow, near-shore areas support a less diverse fauna than the deeper stations near the edge of the Continental Shelf. This pattern can be disrupted, however, by coarse sediment, hard substrate areas such as the Florida Middle Ground located in Transect III where diversity may be less than on either the shoreward or seaward side.

2) Living percentages increase to the north and west, with the highest percentages being recorded in the areas immediately influenced by Mississippi runoff off the coast of Mississippi and Alabama. The

percentages were higher in the first year than the second in this area, and this may be due to the greater amount of runoff in 1974 than in 1975. There were also much higher percentages of stress indicator species such as Ammonia beccarii in 1974.

3) Living percentages are high for areas of low sedimentation rates, especially the areas off the Florida coast. Initially it was thought that. this reflected a seasonal bloom since many juvenile forms were observed. This may be part of the answer, but since the 1975-76 samples produced equally high living percentages off Florida , and more adult specimens of these same species were present , other causes for the high percentages must be sought. In most bays on the west coast of Florida the sediment is composed mainly of quartz sand, an environment which is somehow creating conditions which result in the dissolution of the $CaCO_3$ tests of the dead foraminifera leaving apparent assemblages with 60-80% live specimens. Although offshore conditions may not be so extreme, the sediment is also primarily composed of quartz sand and, at least some dissolution may be occurring.

4) The numbers of specimens increase with decreasing sediment size. This may simply be a result of physically more specimens in the smaller size fractions, but it may also be that there is a greater source of nutrients and food supply available in the finer sediments, which would support a larger population.

5) The upper limit of the depth habitat for Cassidulina curvata and C. subglobosa decreases northward. In the southern transects these two species are found in abundance only at the deeper stations, but in

Transect V they occur in abundance at all stations in the transect including the shallowest ones. In Transect VI they also occur at stations shallower than to the south. This may be a result of latitude where the shallower depths of Transects V and VI may have temperatures similar to the deeper stations of Transects I-IV. This is unlikely.

The Loop Current may also be affecting bottom currents which carry bottom water from greater to shallower depths bringing with it conditions which permit survival of species indigenous to the greater depths. There are several other deeper water species which occur at the same stations, although not in abundance. The Loop Current is apparently carrying a planktonic fauna with it into water shallower than normal for their survival. The planktonic/benthonic ratios are much too high for the depths encountered. Further seasonal sapling should indicate whether or not species abundances of C. curvata and C. subglobosa coincide with the presence of the Loop Current.

6) The shallowest stations of Transects I-IV contain foraminiferal faunas with large numbers of specimens of several species attached to individual quartz grains. Some of these species, especially Asterigerina carinata and Rosalina concinna, have always been described as free-living. This is the first attached occurrences of these two species known to this author. The stations with large percentages of the attached forms are all in approximately 10-33 m of water where current action shifts the sand bottom. The foraminifera are obviously using the quartz grains to which they are attached as anchors to allow them to exist in an environment which otherwise might prove hostile. The two species mentioned above are free-living at the other stations where they occur.

There is also a noticeable orientation in mode of attachment in the attached species. Hanzawaia strattoni, Rosalina concinna, Cibicides cf. C. floridanus, Remaneica sp., a few Rosalina columbiensis all attach with their apertural sides down. Globulina caribaea attaches to the quartz grains by some other part of the test than the aperture, Asterigerina carinata attaches by its aperture, but in every observable instance it orients its test in an upright position perpendicular to the plane of its width.

Another aspect which is invaluable in environmental monitoring is the presence of stress indicator species. Ammonia beccarii is represented in abundance by two varieties at only the shallower stations of Transect VI (Area 5) and at station 2101, Transect I. It is considered here for its potential for indicating stress placed on the environment by activities associated with petroleum exploration and production. It is a well-known indicator, occurs over vast areas of the world ocean, and is well studied. The fact that it occurs in every transect, although usually in very low frequencies, provides an indicator species for monitoring. With increasing stress placed on the environment, from whatever source, this species will increase in abundance as the normal fauna finds it more difficult to survive. It also provides a method for measuring recovery time from environmental contamination by recording the time necessary for an area to change from a fauna dominated by A. beccarii to that of its normal species composition. Other stress indicator species which are present in the MAFLA area are Nonion depressulum matagordanum and the various species of Elphidium.

If the stress conditions become so great that only a monospecific fauna remains, the degree of stress can also be determined by measurements of deformed chambers and changes in wall thickness of A. beccarii.

Although this report deals principally with the living fauna, it is worth examining the total fauna with regard to Amphistegina gibbosa. This species occurs live in abundance at different depths in different transects, always in association with coarse sediment. The genus is a world-wide reef indicator and most species belonging to it are always associated with reefs or high energy, hard substrates. The percentages of A. gibbosa in the total fauna are far greater than in the living fauna, and the majority of them show signs of reworking, indicating a relict fauna. Other reef species, at times abundant in the relict fauna, but rare in the living fauna, are Archaias angulatus and Peneroplis proteus. The presence of A. angulatus in the relict fauna, but its absence, or at least only a rare occurrence, in the living fauna indicates a Late Pleistocene or Early Holocene reef, thriving at a time when the water temperatures were warmer than those of today. In the Gulf of Mexico-Caribbean region at present, A. angulatus is not able to survive in cool water temperatures (Seiglie, 1968). Parker and Curray (1956) and Ludwick and Walton (1957) arrived at similar conclusions, the former based on the faunal evidence of mollusks and corals with abundant lithothamnoid algae and bryozoans, and the latter on skeletal remains of foraminifera, calcareous algae, mollusks, stony corals and bryozoans. Both papers stated that the water was much shallower and warmer than at present.

A comparison of the living benthonic foraminiferal faunas in the MAFLA area over the three sampling periods indicates changes in species composition are minor for the major dominant species, but changes in species distribution and especially abundance do occur naturally. At most stations these changes are relatively unimportant while at a few they are extreme, The causes for extreme change at a station while one immediately adjacent has little change are not completely understood at present. Additional seasonal sampling should clarify these changes. In general most stations showed minor changes in species abundance from the May-June to September sampling periods. Twenty stations showed an increase, twenty showed a decrease and three remained essentially Unchanged. In most cases the changes were minor. From September to January nine stations showed an increase in foraminiferal abundance, thirty-five showed a decrease and three showed essentially no change. Seven of the nine stations showing an increase were located in Transects V and VI, which were sampled immediately after Hurricane ELOISE, most of the rest showed considerable decreases in abundances of the living fauna, over 80% at some stations. The increases could be due to increased productivity produced by disturbance of bottom sediments by the hurricane. The decreases are probably associated with adverse winter conditions. Much more numerous and smaller specimens were noticed during the May–June and September sampling periods, probably reflecting times of maximum reproduction occurring during the warm summer months.

A comparison of the 12-15 cm and surface three cm of the total faunas indicates some minor changes occurring in the foraminiferal faunas, but for the most part the major dominant species remained the same.

STATISTICAL ANALYSIS

The following statistical parameters were calculated using living foraminiferal data: Correlation between mean grain size and foraminiferal abundance, Shannon–Weaver diversity and evenness indices, Sander's affinities and Montford cluster analysis.

Correlation coefficients for mean grain size and live foraminiferal abundance were calculated for each of the A and K replicates using:

$$\frac{\Sigma\ (Xi-\bar{X})\ (Yi-\bar{Y})}{[\Sigma\ (Xi-\bar{X})^2\quad \Sigma\ (Yi-\bar{Y}\ ^2)]^{\frac{1}{2}}}$$

where Xi is the foraminiferal abundance of the i-th sample and Yi is the mean grain size of the i-th sample. For the living population as a whole the only significant correlation noted was for the greater than 500 µm size range which had 0.86097 and 0.91551 correlation coefficients for the A and K replicates respectively. Although correlations were low for living populations there are strong indications that grain size of sediment does control distribution of certain individual species.

Diversity and evenness for all stations are listed in Table 1. Diversity plotted by Transect (Figs. 1-2) shows the normal expected increase seaward for Transects I-III. Transect IV shows the same general trend with the exception of station 24 for the second and third seasonal samplings. This is undoubtedly due to the very coarse sediment encountered at these times where diversity is affected by grain size. Transect V and VI show no appreciable seaward increase in diversity.

	June 1975		September 1975		January 1976	
Station #	H’	J’	H’	J'	H’	J'
2101	2.6124	0.7348	2.4084	0.6774	2.1983	0.6597
2102	2.7515	0.7678	2.0311	0.6032	2.1261	0.6451
2103	3.1515	0.7938	3.6032	0.8111	3.1896	0.7822
2104	3.2224	0.8155	3.1016	0.7376	2.5837	0.6787
2105	3.1823	0.7542	3.1241	0.7540	2.8276	0.6825
2106	3.4256	0.8176	3.4986	0.3007	3.1624	0.7965
2207	2.0032	0.5343	1.9830	0.6036	2.1282	0,6457
2203	3.1015	0.7328	3.0470	0.7’871	2.6237	0.7020
2209	3.1630	0.7929	3.1560	0.7876	3.0503	0.7335
2210	3.4707	0.8283	3.423.<	0.7980	3.0147	0.7558
2211	3.3934	0.8255	3.2340	0.7334	3.1022	0.7577
2212	3.4987	0.8235	3.2631	0. 8003	3.1243	0.8256
2313	3.2276	0.7949	3.2042	0.7603	2.9507	0.7468
2314			3.5515	0.8037	3.4002	0.8271
2315			3.1869	0.7752	3.0862	0.7701
2316	3.2477	0.3104	3.0106	0.7583	2.7830	0.7544
2317	3.1927	0.7897	2.3532	0.7304	2.2.643	0.7258
2318	2.1349	0.6217	1.7397	0.5628	1.6385	0.5226
2419	1.8653	0.5382	1.9673	0.5784	2.2240	0.6206
2420	1.6640	0.5170	2.1153	0.5950	0.9974	0.5126
2421	2.6260	0.6783	2.4841	0.6350	2.6451	0.6727
2422	3.3331	0.8045	2.6023	0.6962	2.1766	0.6532
2.423	3.0563	0.7559	2.7746	0.7207	2.7726	0.7466
2424	3.0844	0.7697	0.4631	0.1303	0.7206	0.4022
2425	3.0684	0.7304	2.6259	0.6981	2.7820	0.7825
2426	3.0331	0.7689	3.2087	0.7775	2.9844	0.7751
2427	3.5234	0.8571	3.0060	0.8095	3.2053	0.7894
2528	3.1285	0.7880	3.0600	0.7744	2.8247	0.8010
2529	3.1378	0.8063	2.9685	0.7798	3.4578	0.8346
2530	3.3671	0.8127	2.9768	0.7395	2.5593	0.7951
2531	3.2074	0.7968	3.3221	0.8114	3.2116	0.8089
2532	3.2291	008172	3.2875	0.8131	3.2262	0.7880
2533	3.1368	0.7828	3.2408	0.7707	3.0876	0.7267
2534	2.7559	0.7119	2.6460	0.6911	2.8150	0.7272
2535	3.1602	0.7687	3.2447	0.7862	3,1992	0.7582
2536	3.3382	0.8187	3.1528	0.7798	2.9927	0.7957
2637	2.5060	0.7231	2.4301	0.7’217	2.5394	0.7541
2638	2.7007	0.7659	2.6474	0.7446	2.4372	0.7773
2639	2.4155	0.6548	2.6538	0.6855	2.5916	0.7074
2640	2.6491	0.7088	2.2706	0.6114	1.9495	0.5625
2641	2.5104	0.6634	2.3835	0.6941	2.6534	0.6818
2642	2.3028	0.6839	2.3354	0.6289	0.8001	0.4465
2643	3.0219	0.7411	3,0363	0.7446	2.6320	0.7135
2644	2.5762	0.7082	2.9084	0.6993	2.9797	0.7308
2645	3.3182	0.7734	2.9495	0.7502	2.9942	0.7343

Table 1. H’ (diversity) and J’ (eveness) measurements for the second year of the MAFIA program.

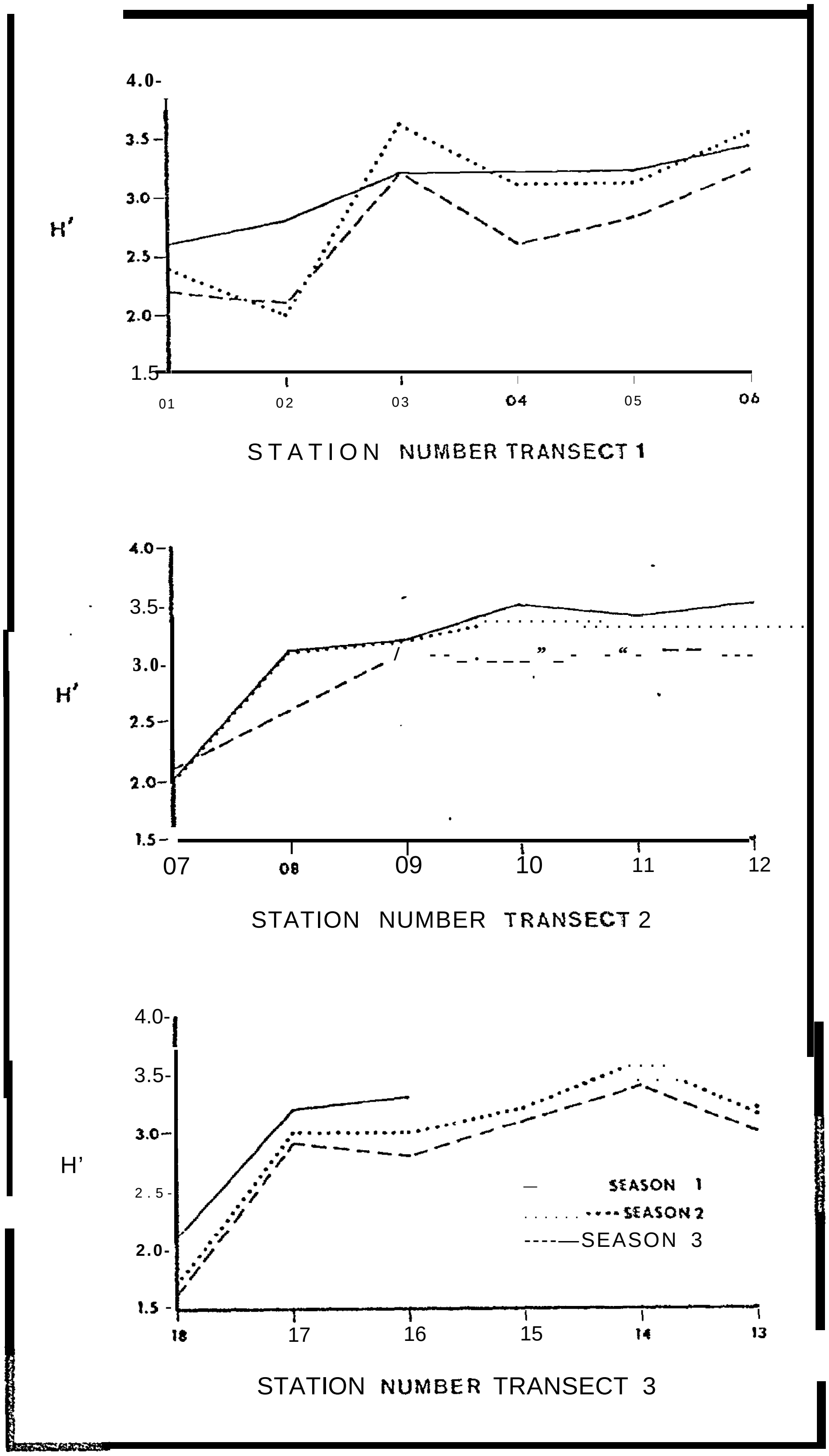

Figure 1. Shannon-Weaver diversity indices plotted by transect.

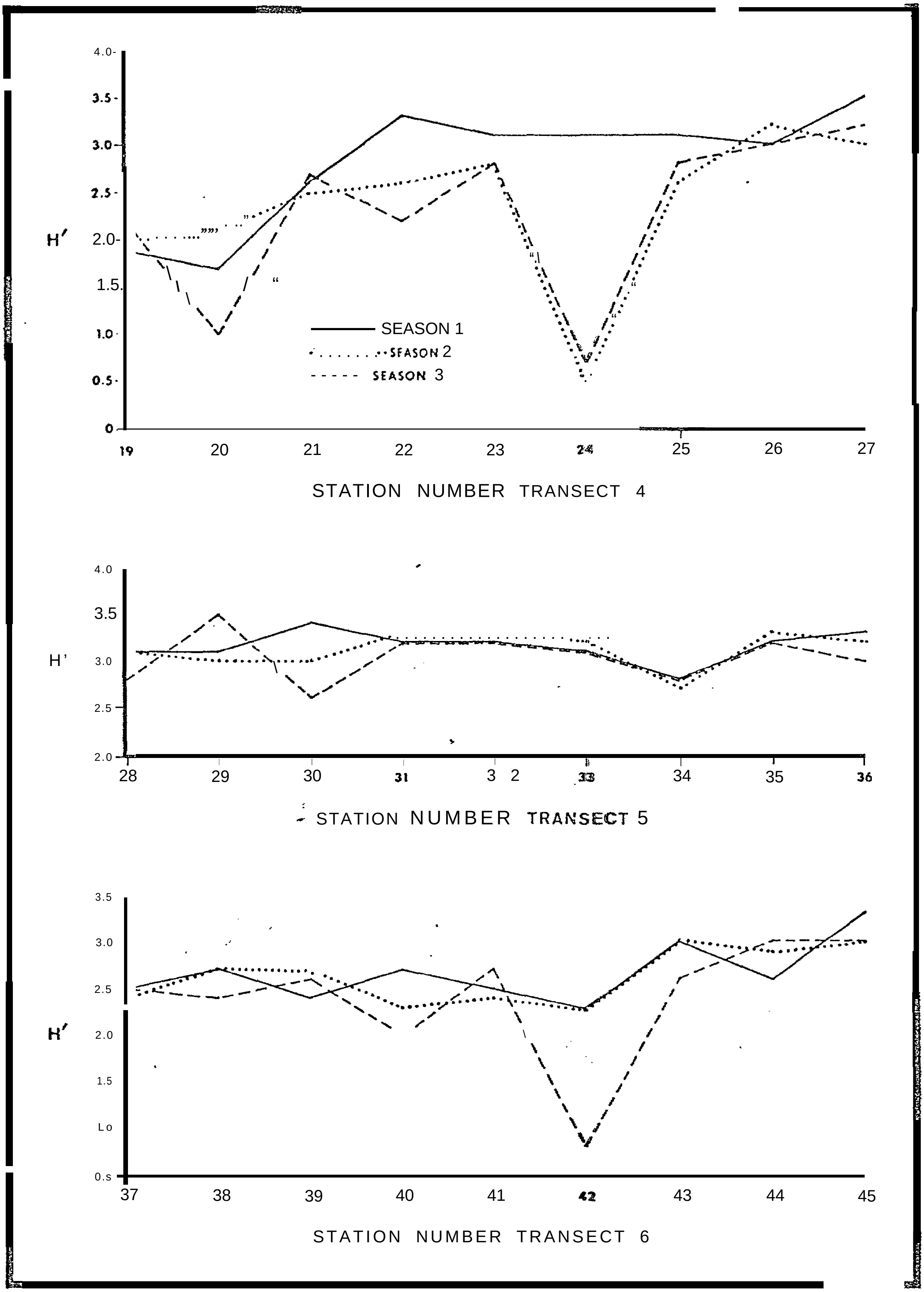

Figure 2. Shannon-Weaver diversity indices plotted by transect.

In Transect V this is due to the number of deeper-water species living farther up the shelf along with the normal species for the depths encountered. Upwelling along the DeSoto Canyon is undoubtedly creating conditions favorable for the deeper-water species , while the fauna normal for those depths are probably more dependent on other parameters such as light penetration, the two factors together providing favorable conditions for the two faunas to coexist and hence causing higher diversity in shallow water. Transect VI does show a slight increase in diversity at the seawardmost stations, but much less so than the clearly defined trends of Transects I-IV. The smoothing out of the curve is probably due to sediment grain size, with the shallowest stations nearest shore being much finer-grained than the deeper offshore stations, a reversal of the trend in the other five transects. The finer-grained sediments support a more diverse fauna inshore even though the habitat may be stressed due to low salinity, highly turbid river runoff water, while the offshore stations are considerably more coarse-grained, and thus support a less diverse fauna even though the habitat is normal marine.

Evenness plotted by transect (Figs. 3-5) shows the same general trends as diversity for Transects I-V for the same reasons stated above. Transect VI, however, again diverges from the general trend by having a U-shaped general curve. The nearshore stations show a high degree of evenness, even though the fauna is stressed, the major dominant species are evenly distributed in abundance. Proceeding offshore (stations 40-42) the dominant species of the coarser sediments are less evenly distributed. The farthest offshore stations again exhibit a high degree of evenness due to to the mixing of a fauna similar to that of stations 40-42 along

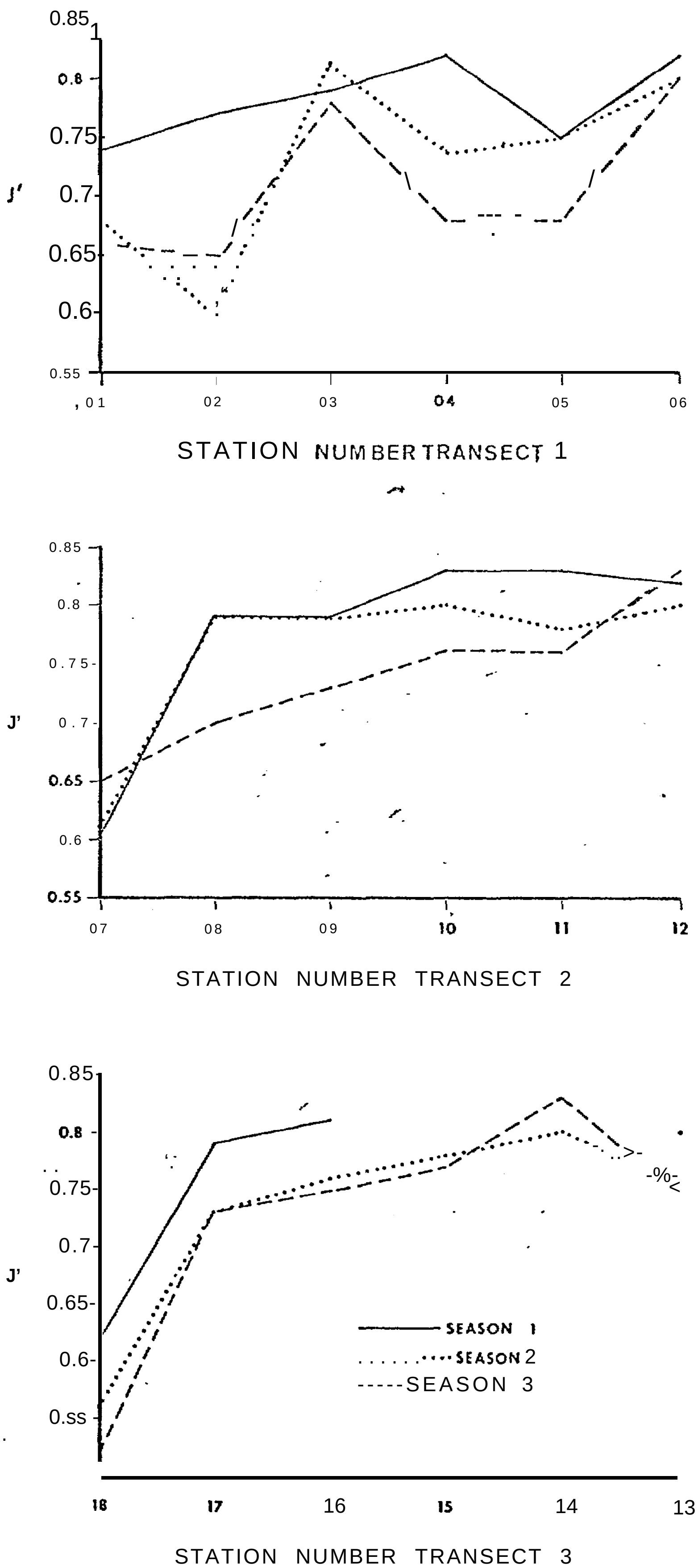

Figure 3. Evenness plotted by transect.

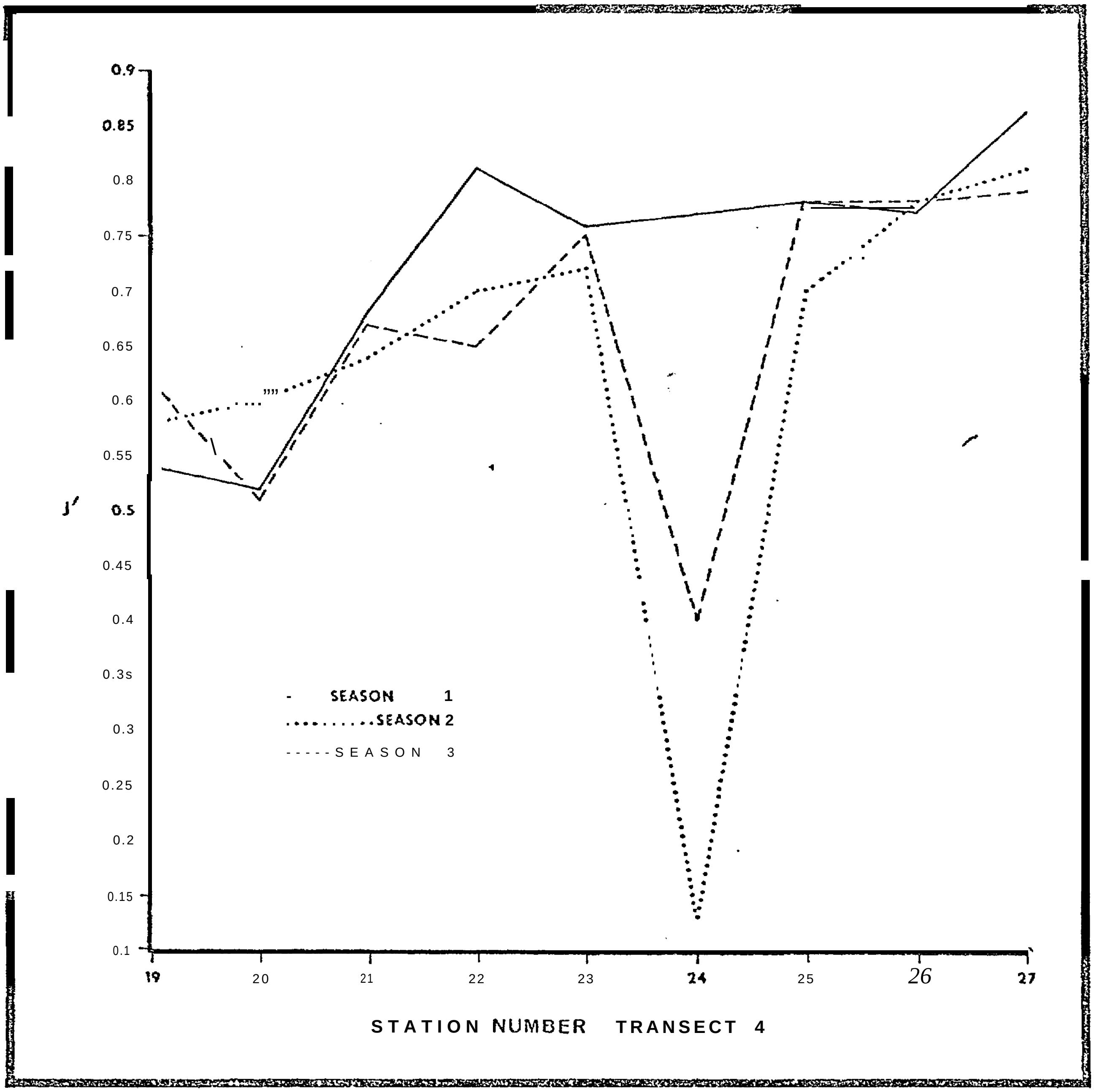

Figure 4. Evenness plotted by transect.

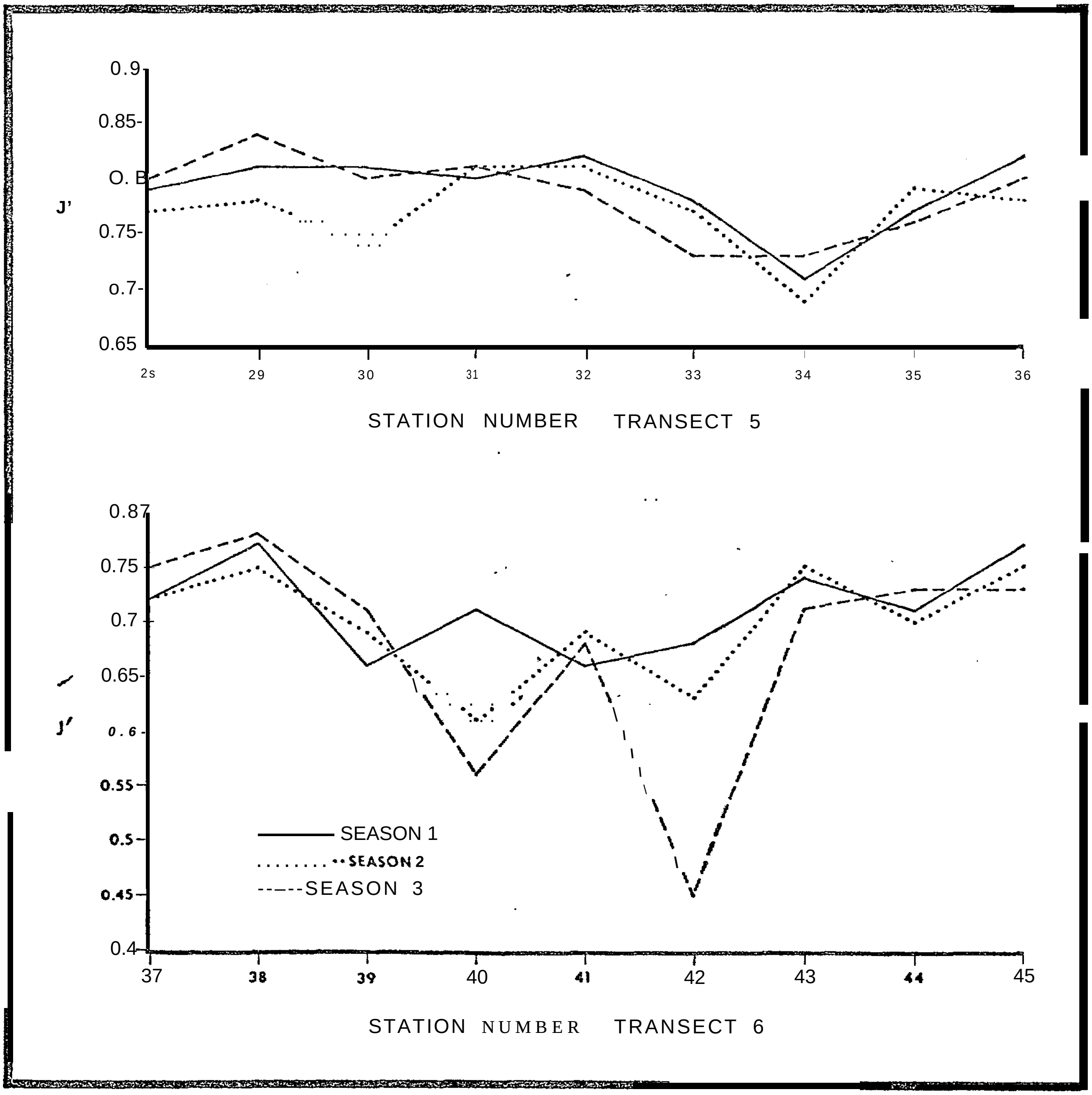

Figure 5. Evenness plotted by transect.

with a reef fauna.

Figure 6 shows diversity and evenness averaged over transects. In general these graphs show a remarkable uniformity of diversity and evenness over the entire MAFLA area. The low points on both graphs reflect the coarseness of sediment over most of Transect IV, and the influence of river runoff in Transect VI.

Sander's affinities indicate the midpoints of each transect are most similar to all other stations in the transects , with the exception of Transect VI where the trend is skewed shoreward by one station. In a north-south trend at the deepest stations (183 m) station 2313, again the midpoint, has the greatest affinity to all other stations in the trend. The near-shore stations of Transects I–IV also shows the highest affinities to all other stations along the north-south trend at the midpoint, station 2318.

Montford cluster analysis shows the greatest affinities between seasonal samplings at the same stations. This reflects a high degree of uniformity of the species composition of the faunas seasonally. The second highest affinities are between adjacent stations, both along transects and north-south trends. The least affinities, as one would expect, are between the shallowest and deepest stations and between distal ends of the overall are a. In general, cluster analysis indicates a high degree of affinity over the entire MAFLA area over all seasons , only four group memberships falling lower than 26.17'74.

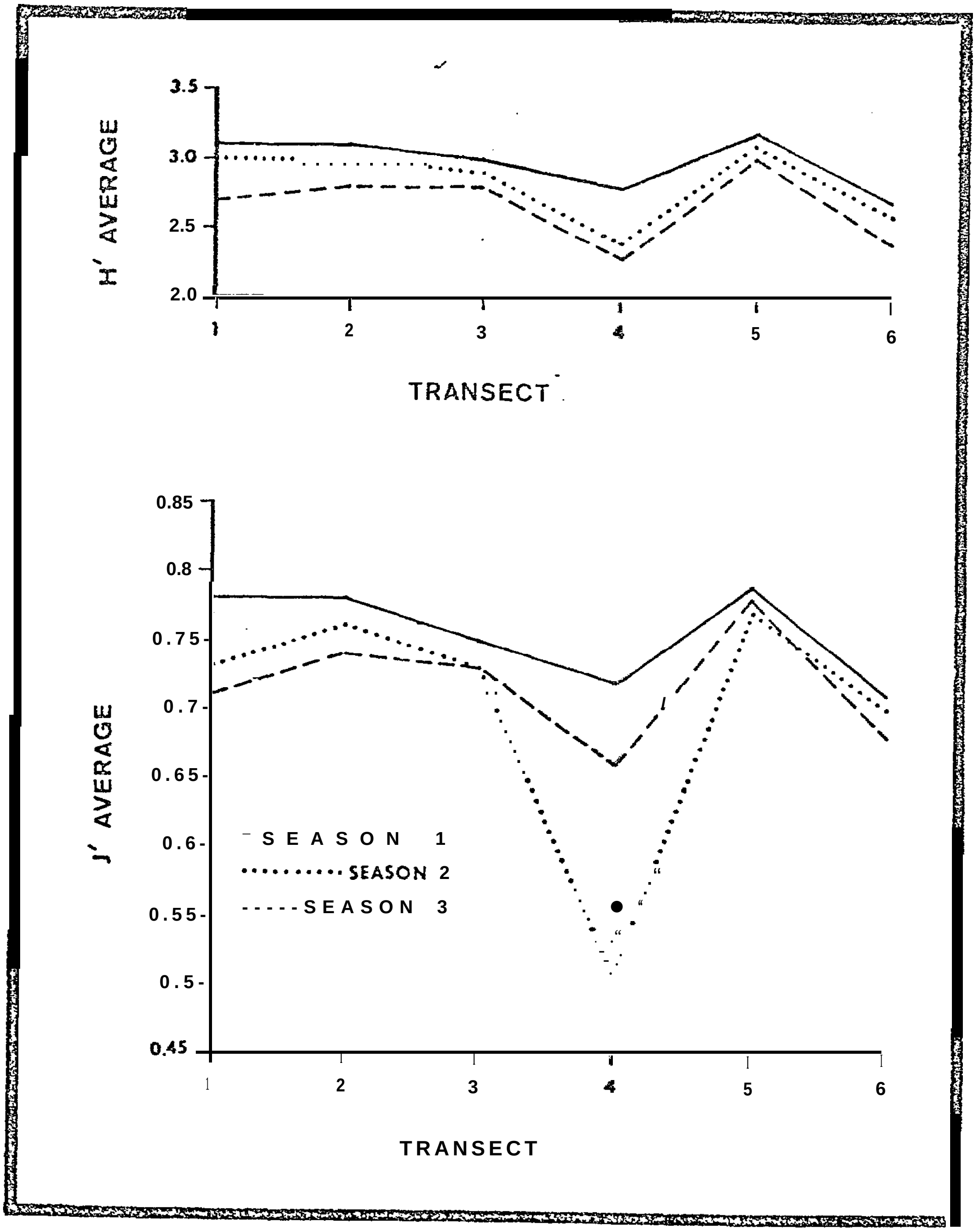

Figure 6. Diversity and evenness averaged by transect.

CONCLUSIONS

A comparison of the living benthonic foraminiferal faunas of the MAFLA area from 1574 and 1975 indicates changes in species distribution and abundance occur naturally. At some stations these changes are relatively unimportant while others are extreme. The causes for extreme change at one station while a station immediately adjacent has relatively little change are not completely understood at present. Seasonal sampling should clarify the causes for these changes.

Several foraminiferal trends have become apparent in the MAFLA area. Many of these are at least partially understood, but, again, seasonal sampling should clarify the reasons for the trends.

Stress indicator species occur in the MAFLA area and further monitoring should enable us to achieve a better understanding of their reactions to natural changes in the environment in addition to providing a means for determining introduction of man-made pollutants and their potential danger to the environment.

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