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Homogeneity and diversity of intertidal polychaete fauna in the Vasishta Godavari estuary

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Abstract. Homogeneity and diversity of the intertidal polychaetes in the Vasishta Godavari estuary are discussed basing on the collections made at six fixed stations during October 1976 and January 1978. Matrix and rarefaction methods are adopted for arriving at homogeneity and diversity respectively. Homogeneity varied along with the salinity structure in the estuary ; high percentage of affinity was observed during the recovery and summer periods while affinity was relatively low during annual freshwater flood period. The factors generally controlling the diversity and the reasons for high polychaete diversity in this estuary are discussed.

Keywords. Matrix method ; rarefaction method ; faunal homogeneity ; species diversity ; physically controlled community.

1. Introduction

Assessment of faunal homogeneity and species diversity in ecological studies has gained importance since the late sixties. Bray and Curtis (1957) and Sanders (1960) recognised the importance of comparing the fauna at two different stations in a given locality or at two geographical regions. In a community study stations are compared on the basis of similarity of organisms found there while in the study of a single group of organisms stations are compared on the basis of species occurring there.

Species diversity is a measure of the number of species present and their numerical composition. It is generally known that some areas are inhabited by a higher number of species than others for which several explanations are offered. Sanders (1968) extensively studied the marine benthic diversity basing on the samples collected from soft bottom marine and estuarine environments covering different geographical localities. While reviewing the existing theories he put forward the stability-time hypothesis (Sanders 1969).

In the present paper, the results of an investigation on the homogeneity and diversity of the intertidal polychaete fauna of the Vasishta Godavari estuary are presented.

2. Area of investigation

The area investigated is the lower 16 km stretch of the Vasishta Godavari estuary (16° 18′ N; 81° 42′ E) on the east coast of India. The location of the stations along the course of the estuary is shown in figure 1. The geographical description of the area and stations were given earlier (Srinivasa Rao 1980).

3. Material and methods

Methods of collection of samples and their analyses were published earlier (Srinivasa Rao 1980; Srinivasa Rao and Rama Sarma 1980). The matrix method suggested by Wieser (1960) and Sanders (1960) and the rarefaction method suggested by Sanders (1968) were adopted to measure the homogeneity and diversity respectively.

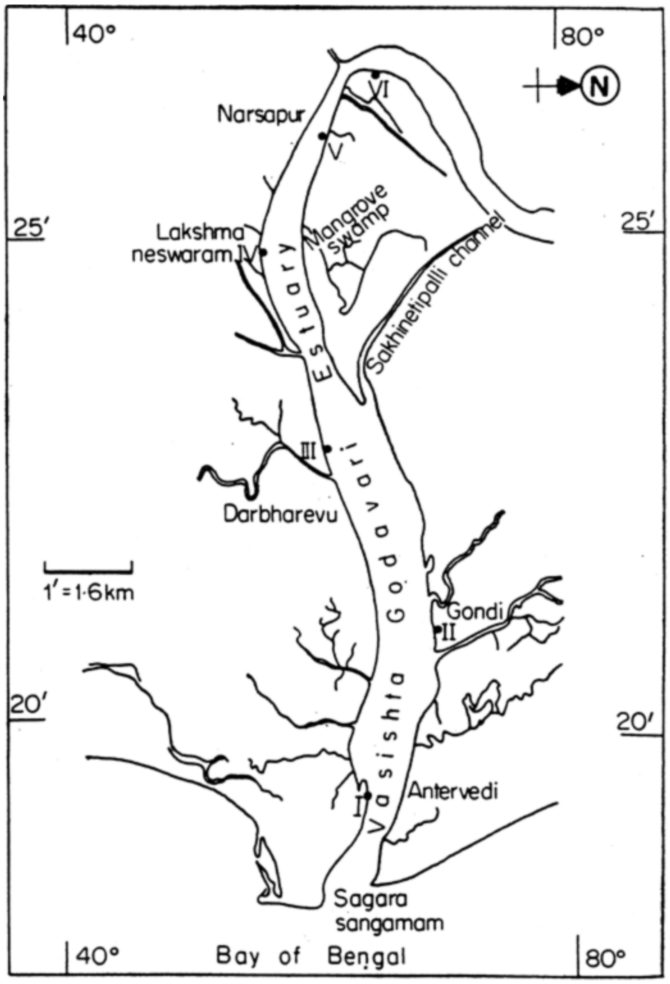

Figure 1. Vasishta Godavari estuary—Location of the stations.

4. Results

Hydrographical and sedimentological characteristics at the six selected stations were described earlier (Srinivasa Rao 1980; Srinivasa Rao and Rama Sarma 1980).

Depending upon the salinity structure in the estuary the year is divided into three well-defined periods; (i) the annual freshwater flood period (July–October) when the entire estuary is filled with freshwater at all levels; (ii) the recovery period (November–February) marked by the cessation of high floods and gradual inflow of neretic waters into the estuary and (iii) the high saline period (March–June) when the neretic waters dominate and salinities around 27‰ are encountered even 16 km up the estuary.

An average density of 499 m^2 of polychaetes was recorded in this estuary. The abundance varied with season, being higher during summer or high saline period than during the annual flood period. The numbers gradually increased from October onwards when the 'seasonal migrants' extended and settled in the estuary (Srinivasa Rao and Rama Sarma 1979). The nephtyd *Nephtys oligobranchia*, the capitellid *Heteromastus similis* and two of the nereids ?*Indonereis* sp. and *Dendronereis arborifera* which appeared throughout the year were the most dominant of the polychaetes. The number of species occurring at each station and the total number of individuals of each species obtained during the study period are shown in tables 1–6.

Table 1. Species composition at station I.

Rank of species by abundance	Number of individuals	Percentage of species	Cumulative percentage
1. *Nereis lamellosa*	5401	45·53	45·53
2. *Heteromastus similis*	2120	17·87	63·40
3. *Magelona cincta*	1286	10·84	72·24
4. *Ancistrosyllis parva*	719	6·01	80·25
5. *Nephtys oligobranchia*	381	3·20	83·45
6. ? *Indonereis* sp.	357	3·00	86·45
7. *Prionospio cirrobranchiata*	333	2·80	89·25
8. *Ceratonereis erythraensis*	240	2·02	91·27
9. *Prionospio cirrifera*	199	1·67	92·94
10. *Dendronereis arborifera*	124	1·04	93·98
11. *Sternaspis scutata*	100	0·84	94·82
12. *Cossura coasta*	99	0·83	95·65
13. *Prionospio saldhana*	83	0·69	96·34
14. *Glycera longipinnis*	74	0·62	96·96
15. *Glycera tessalata*	73	0·61	97·57
16. *N. neanthes capensis*	66	0·55	98·12
17. *Prionospio pinnata*	58	0·48	98·60
18. *Glycera alba*	50	0·42	99·02
19. *Isolda pulchella*	49	0·41	99·43
20. *Lumbrinereis heteropoda*	16	0·13	99·56
21. *Namalycastis indica*	16	0·13	99·69
22. *Mystides southerni*	16	0·13	99·82
23. *Diopatra neapolitana*	8	0·06	99·88
24. *Glycinde oligodon*	8	0·06	99·94
25. *Pilargis* sp.	8	0·06	100·00

Table 2. Species composition at station II.

Rank of species by abundance	Number of individuals	Percentage of species	Cumulative percentage
1. *Heteromastus similis*	7104	39·51	39·51
2. *Dendronereis arborifera*	2781	15·47	54·98
3. *Nephtys oligobranchia*	2487	13·83	69·81
4. *Magelona cincta*	1425	7·93	76·74
5. ?*Indonereis* sp.	1197	6·66	83·40
6. *Ancistrosyllis parva*	350	1·95	85·35
7. *Nereis lamellosa*	291	1·62	86·97
8. *Polydora kempi*	291	1·62	88·59
9. *Prionospio cirrifera*	266	1·48	90·07
10. *Ceratonereis erythraensis*	263	1·47	91·54
11. *N. neanthes capensis*	258	1·44	92·98
12. *Prionospio krusadiensis*	201	1·11	94·09
13. *Prionospio pinnata*	183	1·02	95·11
14. *Glycera alba*	181	1·00	96·11
15. *Prionospio cirrobranchiata*	108	0·60	96·71
16. *Nectoneanthes ijimai*	92	0·51	97·22
17. *Glycera tessalata*	75	0·42	97·64
18. *Prionospio saldhana*	74	0·41	98·05
19. *Lumbrinereis heteropoda*	67	0·37	98·42
20. *Dendronereis* sp.	50	0·28	98·70
21. *Diopatra neapolitana*	50	0·28	98·98
22. *Phyllodoce tenuissima*	33	0·18	99·16
23. *Ceratonereis costae*	33	0·18	99·34
24. *Mystides southerni*	24	0·13	99·47
25. *Glycera longipinnis*	24	0·13	99·60
26. *Cossura coasta*	24	0·13	99·73
27. *Glycera lancadivae*	17	0·09	99·82
28. *Trochochaeta* sp.	17	0·09	99·91
29. *Pulliella armata*	16	0·09	100·00

For arriving at homogeneity, the percentage composition of each species at each station is determined. Then the stations are arranged linearly at right angles along the ordinate and abscissa and all possible pairs are compared regarding their faunal content. The resultant value, the index of affinity, is considered as a measure of percentage of species common to a pair of stations. The index of affinity is obtained by summing up the smaller percentages of the species present in both the samples. The tables are then rearranged so that samples with the highest values are brought into closer proximity. The samples that are ecologically alike are thus grouped together as evidenced in trellis diagrams (figure 2).

For the determination of diversity all the samples collected during the 15-month study period are pooled and all the species are ranked by abundance and the percentage composition determined. The cumulative percentages are presented (tables 1 to 6).

Table 3. Species composition at station II.

Rank of species by abundance	Number of individuals	Percentage of species	Cumulative percentage
1. *Nephtys oligobranchia*	5520	30·12	30·12
2. *Dendronereis arborifera*	3527	19·25	49·37
3. *?Indonereis* sp.	3348	18·27	67·64
4. *Heteromastus similis*	3008	16·42	84·06
5. *Prionospio cirrobranchiata*	467	2·55	86·61
6. *Prionopsio cirrifera*	365	1·99	88·60
7. *Prionospio saldhana*	342	1·87	90·47
8. *Magelona cincta*	314	1·71	92·18
9. *Ceratonereis erythraensis*	216	1·18	93·36
10. *Prionospio krusadiensis*	174	0·95	94·31
11. *Glycera tessalata*	164	0·89	95·20
12. *Glycera alba*	164	0·89	96·09
13. *Ancistrosyllis parva*	124	0·68	96·77
14. *Prionospio pinnata*	117	0·64	97·41
15. *N. neanthes capensis*	107	0·58	97·99
16. *Dendronereis* sp.	58	0·32	98·31
17. *Sternaspis scutata*	58	0·32	98·63
18. *Cossura coasta*	49	0·27	98·90
19. *Polydora kempi*	41	0·22	99·12
20. *Nereis lamellosa*	33	0·18	99·30
21. *Lumbrinereis heteropoda*	33	0·18	99·48
22. *Glycera longipinnis*	33	0·18	99·66
23. *Pulliella armata*	25	0·13	99·79
24. *Nectoneanthes ijimai*	17	0·09	99·88
25. *Glycera lancadivae*	8	0·04	99·92
26. *Diopctra neapolitana*	8	0·04	99·96
27. *Isolda pulchella*	8	0·04	100·00

First the number of species at 25 individuals level is determined. Since 25 specimens in the reduced sample represent 100% of the number of individuals present, then each specimen forms 4% of the sample. Thus it is evident from table 1 that each of the first 4 species comprises 4% or more and in total amounts to 80·3% of the sample. Thus each of the 4 species will represent in the reduced sample. This leaves out a residue of 19·7% of the original sample accounting for the remaining 21 species. As none of these species forms more than 4% of the original sample, the remaining species are not represented at the 25 individual level. To fit the remaining species left out into the 25 individual level the following procedure is adopted. Since one specimen comprises 4% of the reduced sample the residual percentage is divided by 4 which gives a value of 4·9 or 5 species. Thus the original 4 species plus the 5 species now obtained work out to a total of 9 species.

Using this analytical method the number of species at different population levels upto the total number of individuals, i.e., at 50, 100, 200, 500, 1,000, etc, for all the stations was determined and represented in figure 3,

Table 4. Species composition at station IV.

Rank of species by abundance	Number of individuals	Percentage of species	Cumulative percentage
1. *Heteromastus similis*	17537	55·51	55·51
2. ?*Indonereis* sp.	5494	17·40	72·91
3. *Nephtys oligobranchia*	4796	15·19	88·10
4. *Nectoneanthes ijimai*	795	2·52	90·62
5. *Dendronereis arborifera*	632	2·00	92·62
6. *Sternaspis scutata*	357	1·13	93·75
7. *N. neanthes capensis*	341	1·08	94·83
8. *Prionospio cirrifera*	271	0·86	95·69
9. *Magelona cincta*	225	0·72	96·41
10. *Glycera alba*	220	0·70	97·11
11. *Ancistrosyllis parva*	198	0·63	97·74
12. *Ceratonereis erythraensis*	125	0·36	98·01
13. *Prionospio pinnata*	107	0·34	98·44
14. *Polydora kempi*	98	0·31	98·75
15. *Neries lamellosa*	82	0·26	99·01
16. *Prionospio cirrobranchiata*	49	0·16	99·17
17. *Glycera tessalata*	49	0·16	99·33
18. *Prionospio saldhana*	42	0·13	99·46
19. *Mystides southerni*	32	0·10	99·56
20. *Cossura coasta*	25	0·08	99·64
21. *Polydontes malanonotus*	16	0·05	99·69
22. *Glycera lancadivae*	16	0·05	99·74
23. *Isolda pulchella*	16	0·05	99·79
24. *Diopatra neapolitana*	16	0·05	99·84
25. *Pilargis* sp.	8	0·02	99·86
26. *Hesione splendida*	8	0·02	99·88
27. *Namalycastis indica*	8	0·02	99·90
28. *Glycera longipinnis*	8	0·02	99·92
29. *Glycinde oligodon*	8	0·02	99·94
30. *Amphicteis gunneri*	8	0·02	99·96
31. *Dendronereis* sp.	8	0·02	99·98
32. *Lumbrinereis heteropoda*	8	0·02	100·00

This method permits each station to generate a single line which is dependent on the shape of the species abundance curve rather than on the absolute number of specimens per sample.

5. Discussion

Previous workers have shown that despite a gradient of environmental factors such as salinity and sediment composition fairly abrupt faunal changes occur along the length of an estuary (Tenore 1972). The distributional range of each species is influenced somewhat differently by the polyfactorial gradient changes in environmental conditions. In addition, biological interactions also influence the ranges thereby playing an important role in the formation of species groupings. Such species groupings can be distinguished by using trellis diagrams (figure 2).

Table 5. Species composition at station V.

Rank of species by abundance	Number of individuals	Percentage of species	Cumulative percentage
1. *Nephtys oligobranchia*	6508	36·64	36·64
2. *Heteromastus similis*	5382	30·22	66·86
3. ?*Indonereis* sp.	1896	10·82	77·68
4. *Dendronereis arborifera*	1169	6·67	84·35
5. *N. neanthes capensis*	799	4·56	88·91
6. *Prionospio pinnata*	242	1·38	90·29
7. *Magelona cincta*	240	1·36	91·65
8. *Prionospio cirrifera*	221	1·26	92·91
9. *Prionospio saldhana*	175	0·98	93·89
10. *Nectoneanthes ijimai*	142	0·81	94·70
11. *Glycera alba*	129	0·73	95·43
12. *Polydora kempi*	121	0·69	96·12
13. *Ancistrosyllis parva*	114	0·65	96·77
14. *Ceratonereis erythraensis*	98	0·55	97·32
15. *Sternaspis scutata*	98	0·55	97·87
16. *Glycera tessalata*	83	0·47	98·34
17. *Mystides southerni*	82	0·46	98·80
18. *Nereis lamellosa*	56	0·32	99·12
19. *Glycera lancadivae*	25	0·14	99·26
20. *Glycera longipinnis*	24	0·13	99·39
21. *Dasybranchus caducus*	24	0·13	99·52
22. *Phyllodoce tenussima*	16	0·09	99·61
23. *Lumbrinereis heteropoda*	16	0·09	99·70
24. *Dendronereis* sp.	16	0·09	99·79
25. *Pullialla armata*	16	0·09	99·88
26. *Leocrates claparidii*	8	0·04	99·92
27. *Prionospio cirrobranchiata*	8	0·04	99·96
28. *Cossura coasta*	8	0·04	100·00

During the annual flood period station I remained distinct. Station II showed high similarity with stations IV to VI and low similarity with station III inspite of station II being nearer to the latter. This low similarity is perhaps due to the differences in the substratum composition. Stations IV, V and VI showed 70% similarity among themselves because of very similar conditions in salinity, silt-clay fraction and organic matter which might have favoured similar polychaete species.

During the recovery phase of the estuary, the hitherto observed distinct nature of station I no more prevailed. It showed more than 25% similarity with all the stations. The average affinity increased to 55·85% during this period as more number of polychaete larvae obviously entered from the neretic end and settled at stations I to VI and thus extended their distiibution higher up the estuary through the establishment of uniformly high saline conditions in the estuarine region.

In summer, because of the greater neretic influence at station I it became distinct again not only in water quality and nature of substratum but also fauni-

Table 6. Species composition at station VI.

Rank of species by abundance	Number of individuals	Percentage of species	Cumulative percentage
1. *Heteromastus similis*	4405	34·67	34·67
2. *Nephtys oligobranchia*	3855	29·68	64·35
3. *?Indonereis* sp.	1974	15·26	79·61
4. *Dendronereis arborifera*	1132	8·76	88·37
5. *N. neanthes capensis*	257	1·95	90·32
6. *Magelona cincta*	205	1·61	91·93
7. *Glycera tessalata*	176	1·34	93·27
8. *Phyllodoce tenuissima*	141	1·10	94·37
9. *Ancistrosyllis parva*	91	0·69	95·06
10. *Ceratonereis erythraensis*	74	0·56	95·62
11. *Lumbrinereis heteropoda*	65	0·49	96·11
12. *Cossura coasta*	65	0·49	96·60
13. *Glycera longipinnis*	58	0·44	97·04
14. *Pronospio cirrifera*	41	0·36	97·40
15. *Prionospio cirrobranchiata*	41	0·36	97·76
16. *Dendronereis* sp.	33	0·25	98·01
17. *Nereis lamellosa*	33	0·25	98·26
18. *Prionospio pinnata*	25	0·20	98·46
19. *Glycera lancadivae*	24	0·19	98·65
20. *Glycera alba*	24	0·19	98·84
21. *Nectoneanthes ijimai*	24	0·19	99·03
22. *Dasybranchus caducus*	17	0·13	99·16
23. *Panthalis oerstedi*	16	0·12	99·28
24. *Namalycastis indica*	16	0·12	99·40
25. *Diopatra neapolitana*	16	0·12	99·52
26. *Polydora kempi*	16	0·12	99·64
27. *Sternaspis scutata*	16	0·12	99·76
28. *Glycinde oligodon*	8	0·08	99·84
29. *Prionospio saldhana*	8	0·08	99·92
30. *Pulliella armata*	8	0·08	100·00

stically. Station II was more similar to stations V and VI than with stations III and IV because of the high density of the capitellid *H. similis*. The organic matter content appears to control the distribution and abundance of *H. similis* rather than the substratum and particle size (Srinivasa Rao 1980). Again stations IV, V and VI showed more than 70% similarity among themselves and an extraordinarily high affinity of 99% prevailed between stations IV and V.

The average percentage affinity for all possible combinations at each station was 43·8% during the annual freshwater flood season, 55·78% during the recovery period and 54·82% during the summer period. The difference in the affinity between flood period and other seasons is probably due to the drastic changes in salinity structure and in the sediment composition caused by high freshwater floods—an annual feature, resulting in mortality of less tolerant organisms. During the recovery phase of the estuary after the freshwater floods the recruitment

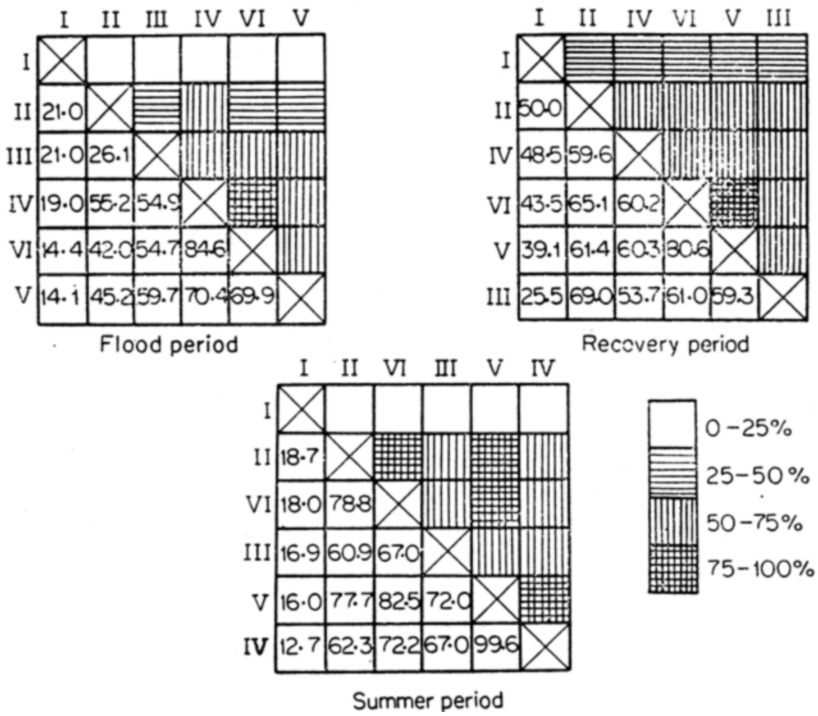

Figure 2. Trellis diagrams showing faunal similarity among six stations during different seasons.

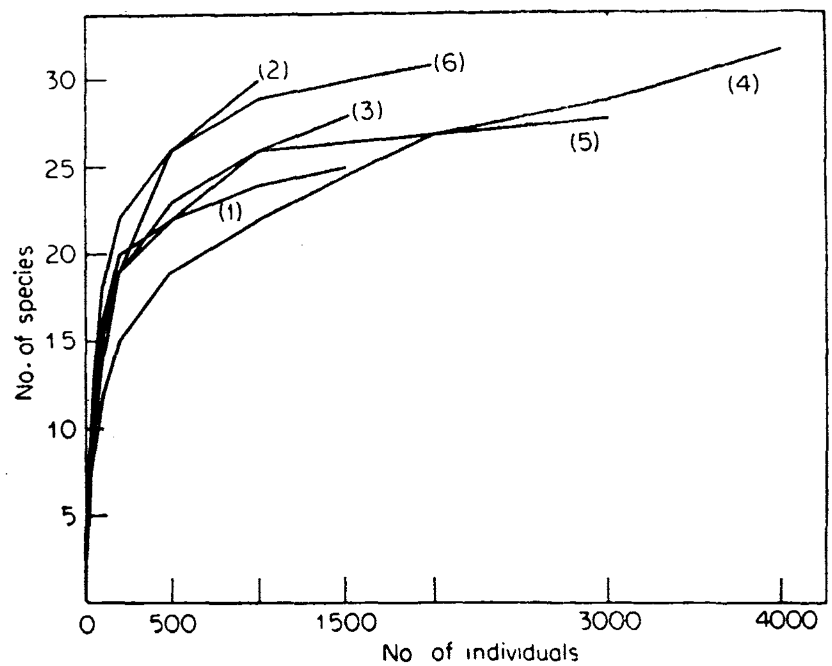

Figure 3. Arithmetical plot of the number of species at different population levels using the rarefaction methodology for stations I to VI in the Vasishta Godavari estuary.

of polychaete larvae from the neretic zone and their settlement at different localities in the estuary raised the affinity. The slight reduction in the percentage of affinity in summer may be due to unpredictable local factors.

While postulating his stability-time hypothesis, Sanders (1968, 1969) distinguished two hypothetical and extreme types of communities namely, physically controlled and biologically accommodated communities. In the first category the highly variable physical factors like temperature, salinity and oxygen control the growth, breeding, metabolism, etc., forcing the organisms to adapt to a broad spectrum of fluctuations in physical conditions. In biologically accommodated communities, because of the constant and uniform physical environment for historically long times, stable, complex and buffered assemblages result characterised by a large number of stenotopic species.

Because of the wide fluctuations in salinity, sediment composition and possibly other physical and chemical parameters, the Vasishta Godavari estuary may be expected to belong to a physically controlled area in the sense of Sanders (1968) and hence to exhibit a low diversity. The salinity ranges from near zero to 35‰, and the substratum at times becomes highly variable making the area under study highly uninhabitable. Similar conditions were recorded in the Vellar estuary (Jacob and Rangarajan 1959) and Kakinada Bay (Rama Sarma and Ganapati 1968). However, all the three areas exhibit high diversity (Sanders 1968).

The high diversity can be mainly attributed to the location of the study area in the tropics and the prevailing high temperatures. It is well known that the tropics are biologically mature when compared to the temperate and polar regions (Fischer 1960) and as such provide several ecological niches (MacArthur 1965). Temperature in the tropics is nearer to the mid-point of temperature range which protoplasm can endure and as such helps the estuarine organisms to adapt to a wide variety of physical stresses (Panikkar 1940; Fischer 1960). Further it has been suggested that the organisms which are present in physically stressed and unpredictable environment for a long time tend to show broad adaptations to these conditions by maintaining a high degree of genetic variability (Grassle 1967). It may not be unreasonable to speculate that several polychaete species dwelling in this estuary may belong to this genetically flexible category and may be termed as opportunistic species.

The substratum composition is known to influence the diversity. The low diversity at stations I and II may be due to the disturbance of sandy substratum under the regime of fast currents and varying inputs of bed load and the observed low organic matter content in the sediments.

The observed high diversity of polychaete fauna of the Vasishta Godavari estuary is consistent with similar studies in other tropical areas (see Sanders 1968) and also in accordance with the high diversity demonstrated in other tropical groups such as decapod crustaceans (Abele 1974), echinoderms and fishes (Briggs 1976) avian fauna (Karr 1976) and gastropods (Spight 1978).

Several theories have been proposed to explain species diversity and these were reviewed by Paine (1966), Sanders (1968) and more recently by Osman and Whitlatch (1978). It is beyond the scope of this paper to fully discuss the relevance of these theories *vis-a-vis* the results of the present investigation. Our studies indicate that faunal diversities depend on short term local changes. The area investigated experiences frequent disturbances of erosional and depositional nature of the substratum, fluctuations in salinity and other unpredictable changes. The observed homogeneity and diversity pattern thus appear to be controlled by these environmental factors. The extent to which biological factors such as the vagaries of larval recruitment, settlement, predation, parasitism, etc., control homogeneity and diversity has not been studied. But from what has been known from other tropical communities, these may be expected to exert some control over homogeneity and diversity pattern of the intertidal polychaetes of the Vasishta Godavari estuary.

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