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Fisheries Branch (Qld Department of Primary Industries) Technical Report

By-catch from the central Queensland prawn fisheries. Part 2. Spatial and temporal changes in by-catch composition and community assemblages

A report to the Great Barrier Reef Marine Park Authority.

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Contents

SUMMARY

A twenty four month sampling programme on trawl by-catch from major fishing grounds in the Great Barrier Reef Lagoon, between 18°S and 19°S was carried out between January 1985 and December 1986. The programme was designed to give an inventory of species which were taken in trawl by-catch, describe their relative abundance, and establish whether spatial and temporal factors influenced by-catch composition. The composition of trawlable fauna very near coral reefs was described, and the relationship between this fauna and that of sites further from reefs investigated.

A total of 475 species/species complexes were identified in this study. Bony fish and decapod crustacea dominated the by-catch. The relative abundance of species was extremely skewed, with the most abundant 5 species making up more than 50 % of the by-catch. The abundance of some of the numerically dominant species showed considerable within year variation. Seasonal effects were associated with these changes in abundance in some of these species.

Stable spatial zonation was a feature of results obtained in the study. Inshore and near shore sample sites had faunas consistently different to each other, and to mid Great Barrier Reef Lagoon and near-reef sample sites. The faunal dissimilarity between near-reef, deeper water sites and mid Great Barrier Reef lagoon sites was consistently less than the variation between these sites and inshore sites. There was no evidence of a sudden transition in the faunal composition of neat reef and mid Lagoonal sites.

Temporal associations were not as strongly defined as site associations. In some instances, there appeared to be a seasonal succession of faunas from one year to the next, but this cycle of seasonally abundant species associations was not a consistent feature of the fauna.

The analytical techniques used in this study demonstrated the difficulty in describing variation in diverse and complex faunas, and in determining the factors responsible for this variability.

INTRODUCTION

Fishermen who trawl for stocks of penaeid prawns (Penaeidae), bay lobsters (Scyllaridae) and scallops (Amusidae) are one of the major users of the Central Section of the Great Barrier Reef Marine Park (Driml 1987). The trawl fisheries, in which some 300 trawlers are employed, have been described in an earlier report (Dredge 1988). The effect of these trawl fisheries upon reef, near-reef and inter-reef biota is a matter of concern to Marine Park administrators. The inter-reef and near-reef demersal fauna is not well known, few descriptions of species composition, faunal assemblages or fauna dynamics of demersal inter-reef fauna having been published (Cannon *et al.* 1987). Before the effects of trawling upon near-reef and inter-reef communities can be assessed, base-line inventories of species presence and associations are required.

In waters of the continental shelf off central Queensland waters (18°S to 21°S), the major prawn fisheries are for tiger prawns (*Penaeus semisulcatus, P. esculentus*) and king prawns (*P. longistylus, P. latisulcatus*). A field study on the biology and fishery for red spot king prawns, *P. longistylus*, was conducted between 1984 and 1986. Spatial and temporal distribution of the species, its reproduction biology, growth and mortality rate have been described (Robertson and Dredge (1986), Dredge (1988), Courtney and Dredge (1989) and Dredge (1990)). A study of trawl by-catch composition from the red spot king prawn fishery was designed as a complimentary two-year programme. In this programme, the species composition and faunal associations of trawl by-catch were examined. Variation in by-catch composition as functions of temporal and spatial factors were important considerations, as was the relationship between off-reef demersal communities and those of coral reefs.

In an introductory examination of data from this study, species composition of trawl by-catch taken on the continental shelf between 18°S and 19°30'S was described by Jones and Derbyshire (1988). A total of 475 species were recorded from a fauna dominated by bony fish (Osteichthyes) and Crustacea. Watson and Goeden (1989) analysed species associations from the 20 sites sampled at monthly intervals in 1985, using presence/absence and abundance of 200 of the most abundant and consistent species. The sample sites included transects from the coast to near-reef environs, inter-reef sites and on major trawling grounds. They described a dynamic community, in which species occurrences and dominance changed both spatially and seasonally. There was, however, a stable dichotomy in terms of the fauna associated with sites. Inshore and coastal sites were consistently differentiated from near-reef and Great Barrier Reef Lagoon sites on the basis of faunal composition. Near-reef and inter-reef sites were differentiated from mid Great Barrier Reef Lagoon sites in a second dichotomy, at a lower level of dissimilarity. There was some interchange in site associations in these latter two groups and the fauna of some sites did not show clear associations with one or the other. Site associations were correlated with depth, substrate composition and distance from shore. Dredge (1988) summarized results from these two papers and demonstrated considerable differences between near-reef faunas and those of coral reefs in the few taxonomic groups for which data were available.

In this report, the initial study of by-catch composition addressing both the nature of changes in faunal assemblages over time and space, and the nature of transition in faunas from the near-reef to mid Great Barrier Reef Lagoon environments (Dredge 1988) have been extended. Temporal variation in abundance of species which were both abundant and important in the formation of faunal assemblages has been examined. The analyses on site assemblages described by Watson and Goeden (1989) have been extended to cover a full 24 months data. Both time and geographic location have been used as a basis for examining variation in faunal assemblages. A more precise examination of the transition from near-reef to inter-reef and mid Great Barrier Reef Lagoon faunas has been made by examining by-catch from finely spaced sites along a transect running from the immediate vicinity of a reef to off-reef habitat in the central Great Barrier Reef Lagoon. Data gathered from these sites offers some insight on the nature of differences between the reef and near-reef faunas.

METHODS

By-catch Sampling

A sampling regime conducted between January and December 1985 on trawl grounds between 18°S and 19°30'S has been described in an earlier report (Dredge 1988). The sampling strategy was altered in January 1986 to allow sites along a near-reef to mid Great Barrier Reef Lagoon transect to be examined. In 1986, monthly samples were taken at 4 new sample sites and 8 of the original 20 sites between January and December (Figure 1). Location, depths and distances from the shore and nearest reef formation of sites sampled in 1986 are given in Table 1. Sites were located on a coast to near-reef transect (sites 1-5), a near-reef to mid Great Barrier Reef Lagoon transect (sites 21-22-23-6-24-20), and an inter-reef site (site 7), which was sampled intermittently. The closest site to Bramble Reef (18°22'S, 146°43'E) (site 22) was located some 400 m from the reef crest and an estimated 200 m from the reef's base.

Samples were taken within two nights of the new moon, using paired 12 m head rope Florida Flyer trawls. The starboard and port nets were made from 50 and 40 mm mesh respectively. Trawl samples were taken in 30 minute shots. Each net swept an area of approximately 27000 m^2 in each shot. By-catch from one net (50 mm stretched mesh except for 12 samples, when catch from the 40 mm mesh net was used because of gear failure) was weighed and a subsample of approximately 10 kg was removed and frozen for later examination. The remainder of the catch was examined for previously unrecorded species. In the laboratory, sample specimens were sorted to specific or generic level, counted and entered into a computerised data base. Substrate samples from each site were obtained using a small bucket dredge in November 1985 and July 1986. A full description of methods utilised to analyse sediment samples for grain size components and carbonate content has been given by Robertson (m/s).

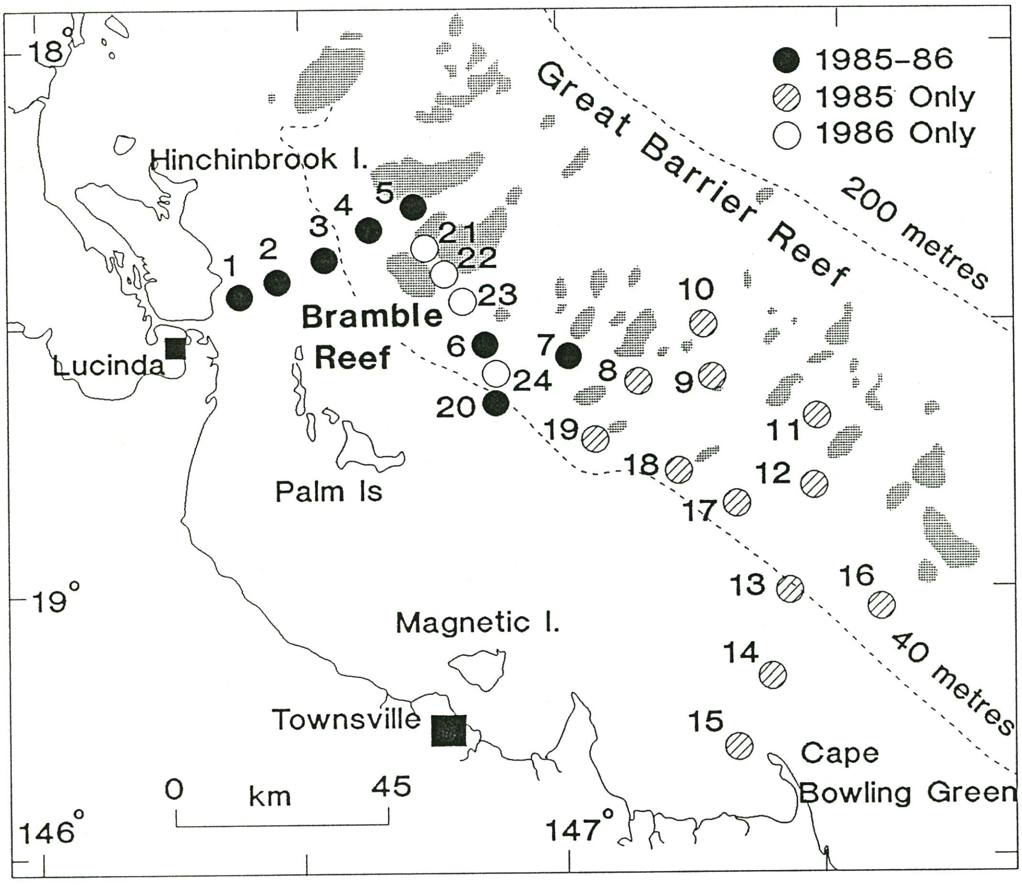

Figure 1. Location of sample sites

Data Analysis

Data were initially sorted to identify those species which occurred rarely or inconsistently, using the SPSS package. On the basis of this examination, species which occurred in fewer than 5% of samples or whose identification was doubtful were omitted from further analysis. The contribution of different taxonomic classes to trawl by-catch were examined and variation in abundance of the most abundant species was plotted as a function of time in an initial examination of the data. By-catch weight and species richness from all samples taken in 1986 were analysed to determine whether they were affected by obvious time series effects, using runs analysis. If no such effects were apparent, two way analyses of variance were conducted on time and site data to determine if either had significant effects upon by-catch weight or species richness.

Site and temporal assemblages were grouped using on the basis of faunal composition of the sample data subset, using the quasi-metric Bray-Curtis measure of dissimilarity, after the data had been log-transformed ($\ln(x+1)$). The CSIRONET package TAXON was used for this numerical classification. Entities (times or sites) were aggregated using a flexible sorting strategy with alpha set at 0.625 and beta at -0.25 (Lance and Williams 1966). Site aggregations were examined on a month by month basis, and for all 1986 samples combined. Data from the 7 sites consistently sampled in 1985 and 1986 were aggregated on a monthly basis. This gave a set of 24 entities which could be examined and grouped on the basis of absence, presence and relative abundance of the 200 attributes (species), thereby giving a time series aggregation. The effect of distance from reef structures upon faunal assemblages was examined using numerical classification. The relative dissimilarity between faunas from near-reef and off-reef sites, and the consistency that near-reef samples showed in grouping with other near-reef, as opposed to off-reef samples, have been used to indicate whether the fauna of near-reef sites had characteristics which allowed for consistent differentiation of these spatially separated sites on biological grounds. Similar examinations have been carried out to determine if a logical time series could be detected from monthly samples.

Table 1. Characteristics of sites sampled in 1986.

Site number	Position (m)	Depth	Distance from shore (km)	Proximity to nearest reef (km)
1	18 27.5S 146 22.5E	17	4.5	31.5
2	18 27 S 146 25.5E	23	9	26
3	18 23 S 146 32.5E	35	20	13
4	18 20.5S 146 38 E	42	31.5	4.5
5	18 17.5S 146 42 E	56	40	1.0
6	18 28.5S 146 48 E	53	50	4
7	18 33.5S 146 58.5E	49	70	4.5
20	18 40.5S 146 52.5E	44	53.5	17.5
21	18 19.5S 146 40 E	44	35	3
22	18 22.5S 146 43 E	49	40.5	0.5
23	18 26 S 146 47 E	53	48	2.5
24	18 33 S 146 48 E	43	50	10

RESULTS

Sampling Programme

In 1986, a total of 133 of the planned 144 samples were obtained. Site 7, a near-reef site which was not on a major transect, was the most frequently missed site, being sampled 5 of the scheduled 12 times. All other sites were sampled between 10 and 12 times. In the 24 month period between January 1985 and December 1986, sites 1-6 and 20 were sampled with the loss of 6 samples (Table 2).

Table 2. Sampling programme for 1985 (Sites 1-6 and 20) and 1986. Sites successfully sampled are indicated as (1), samples not collected are shown as (0).

	Site											
	1	2	3	4	5	6	7	20	21	22	23	24
Month												
1985												
1	1	1	1	1	1	1	1	1				
2	1	1	1	1	0	1	1	0				
3	1	1	1	1	1	1	0	0				
4	1	1	1	1	1	1	1	0				
5	1	1	1	1	1	1	1	1				
6	1	1	1	1	1	1	1	1				
7	1	1	1	1	1	1	1	1				
8	1	1	1	1	1	1	1	1				
9	1	1	1	1	1	1	1	1				
10	1	1	1	1	1	1	1	1				
11	1	1	1	1	1	1	1	1				
12	1	1	1	1	1	1	1	1				
1986												
1	1	1	1	1	1	1	0	1	1	1	1	1
2	1	1	1	1	1	1	0	1	1	1	1	1
3	1	1	1	1	1	1	0	1	1	1	1	1
4	1	1	1	1	1	1	0	1	1	1	1	1
5	1	1	1	1	1	1	0	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	0	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1
9	1	0	1	1	1	1	0	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	0	1	1
12	1	1	1	1	1	1	0	0	1	1	1	1

Sediment Analysis

Details of sediment analysis are given in Table 3. The site nearest the shore (Site 1) was markedly different to other sites, with high clay and silt fractions. There was some evidence of a transition from a site with fine sediments (the inshore site 1) through (terrigenous) sand and gravel sites (2 and 3) to sandy and gritty sites in the mid great Barrier Reef Lagoon area. Maxwell (1973) described similar transitions in sediment from the coast seawards, and associated the changes with transition from terrigenous to biogenic sediments. The very coarse sediments observed at site 22, located in a narrow (< 1 km wide) channel between Bramble and Trunk Reefs, may have been associated with rapid tide run in the channel, and the high proportion of silt found at site 5 coincided with the greatest depth for any of the sample sites.

Table 3. Sediment characteristics of sites sampled in 1986.([1])

Site number	Gravel(%)	Sand(%)	Silt(%)	Clay(%)	Mean particle size (0)	Organic Carbon(%)
1	0.00	17.10	62.26	20.60	6.70	8.83
2	7.42	62.01	19.95	10.62	2.78	4.40
3	7.30	88.72	2.15	1.83	0.93	3.51
4	3.52	77.80	14.14	4.54	2.36	4.81
5	2.06	68.79	25.51	3.64	2.63	4.97
6	3.62	83.16	9.49	3.72	2.63	4.90
7	7.95	84.71	4.18	3.16	1.35	5.22
20	3.76	89.01	4.53	2.69	1.88	4.09
21	2.85	84.89	9.44	2.82	1.69	3.79
22	25.96	56.50	14.70	2.84	1.97	5.32
23	2.07	83.69	11.69	2.55	2.85	4.19
24	5.11	83.90	8.08	2.91	1.71	4.76

([1]) From Robertson (m/s)

Species from the By-catch

The 475 species which were taken as by-catch in the 1985-6 sampling programme are listed in Appendix 1. The 200 species used in community analysis are ranked in order of abundance on the basis of frequency of occurrence in 1986 subsamples. The relative abundance of these 200 species was extremely skewed (Figure 2), with the most abundant five species comprising more than 52% of total by-catch. The 20 most abundant species taken from sites sampled in both 1985 and 1986 (1,2,3,4,5,6,20) have been ranked in order of abundance and compared with the equivalent abundance ranking from 1985 data (Table 4). The variation between ranks of abundance was significant (Spearman rank correlation test, $R_s = 0.77$, $Z = 3.83$, $P<0.05$). Two species which did not appear in the 1985 rankings of 10 most abundant species were present in the 1986 set. Both species were rare at inshore sites and abundant at near-reef and mid-Great Barrier Reef lagoon sites. The two species, ranked 9 and 10 from the 1985 relative abundance data, were ranked 13 and 16 respectively in the 1986 set.

Table 4. Twenty most abundant by-catch species from 1985-6 sampling programme.

Rank	1985 Species	1986 Species
1.	*Metapenaeopsis {rosea {mogiensis*	*Metapenaeopsis {rosea {mogiensis*
2.	*Maretia planulata*	*Portunus tenuipes*
3.	*Engyprosopon grandisquama*	*Trachypenaeus* spp
4.	*Trachypenaeus* spp	Maretia planulata
5.	*Portunus tenuipes*	*Nemipterus celebicus*
6.	*Paramonocanthus japonicus*	*Paramonocanthus japonicus*
7.	*Upenaeus* sp.1	*Engyprosopon grandisquama*
8.	*Amusium balloti*	*Portunus argentatus*
9.	*Portunus rubromarginatus*	*Upenaeus* sp.1
10.	*Lepidotrigla calodactyla*	*Amusium balloti*
11.	*Portunus argentatus*	*Penaeus longistylus*
12.	*Nemipterus* spp.	*Charybdis truncata*
13.	*Penaeus longistylus*	*Portunus rubromarginatus*
14.	*Hypodytes carinatus*	*Sorsogonia tuberculata*
15.	*Sorsogonia tuberculata*	*Suggrundus* spp.
16.	*Trachinocephalus myops*	*Lepidotrigla calodactyla*
17.	*Torquigener tuberculiferus*	*Hypodytes carinatus*
18.	*Saurida undosquamis*	*Sepia* spp
19.	*Prisotis jerdoni*	*Parapercis nebulosa*
20.	*Dactyloptena papilio*	*Saurida undosqamis*

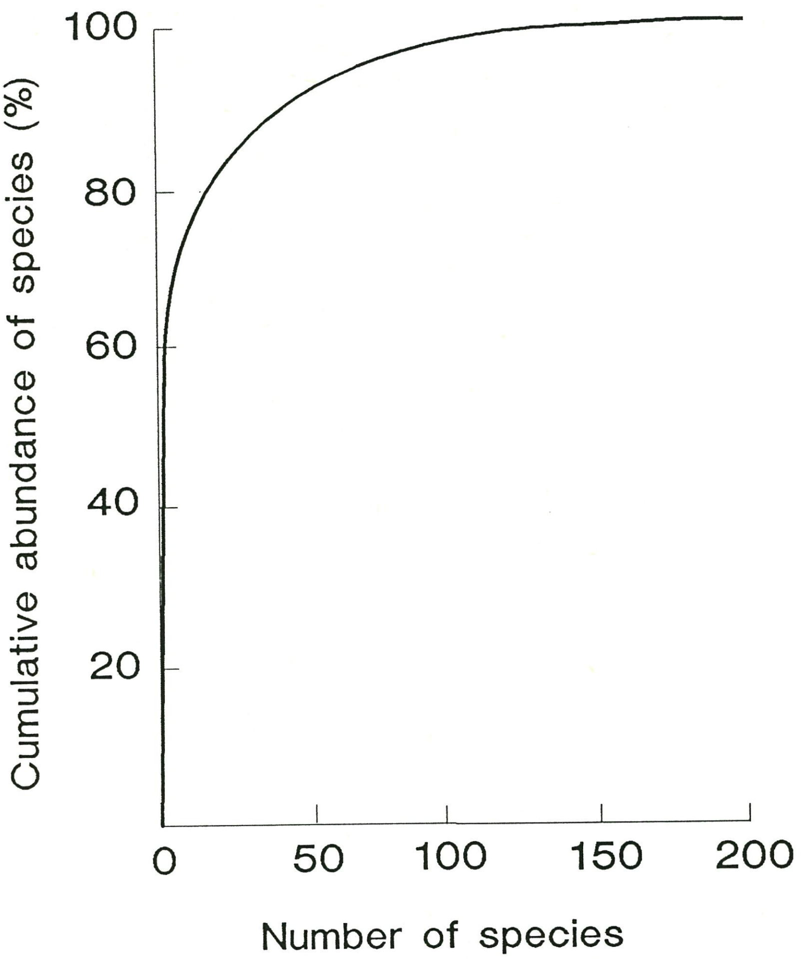

Figure 2. Cumulative abundance of by-catch species in 1986 samples

Changes in Abundance of Species Over Time

The ten most abundant species from 1986 samples were identified, and their relative abundance was considered over the 24 months in which sampling took place. Data from sites 1-6 and 20 (those sites sampled consistently in 1985 and 1986) were used in this examination. Monthly abundance was related to the numbers of each species sampled in each year. Results have been plotted in Figure 3. Five of the 10 species *(Metapenaeopis rosea/mogiensis, Portunus tenuipes, Paramonocanthus japonicus, Portunus argentatus* and *Amusium balloti)* appeared to have annual cycles of abundance. However, time series auto correlation tests incorporating 2 to 12 month lags failed to demonstrate statistically significant trends in abundance for any of the species examined during these time lags. (Figure 4). *Maretia planulata* and *Parupenaeus* sp. 1 were irregularly abundant over time, *Engyprosopon grandisquama* appeared to be irregularly rare and *Trachypenaeus spp.* and *Nemipterus celebicus* maintained stable numbers over time.

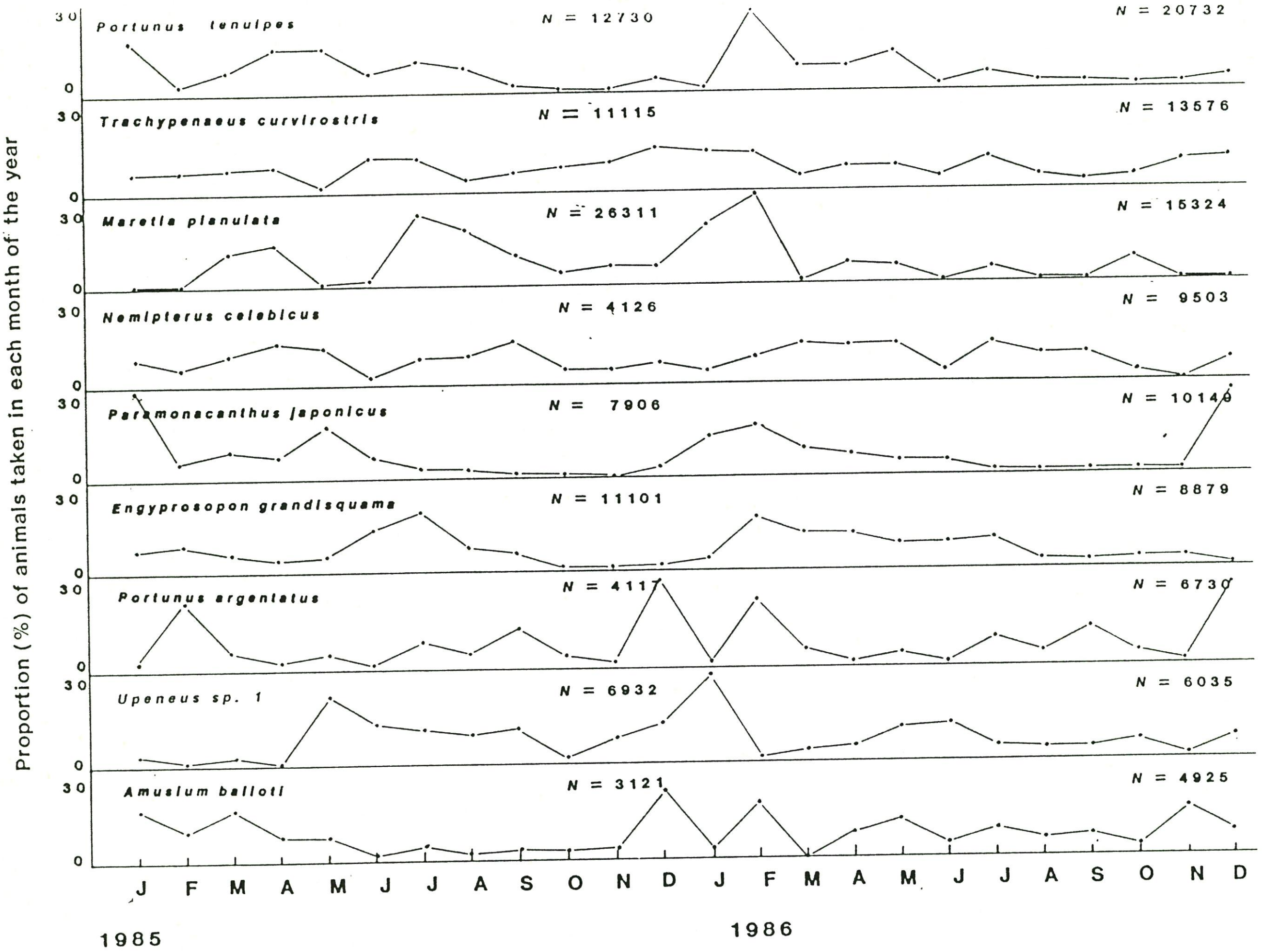

Figure 3. Relative abundance of 10 most abundant species in 1986 subsamples over 24 months (1985 to 1986). Data from sites 1 to 6 and 20 only.

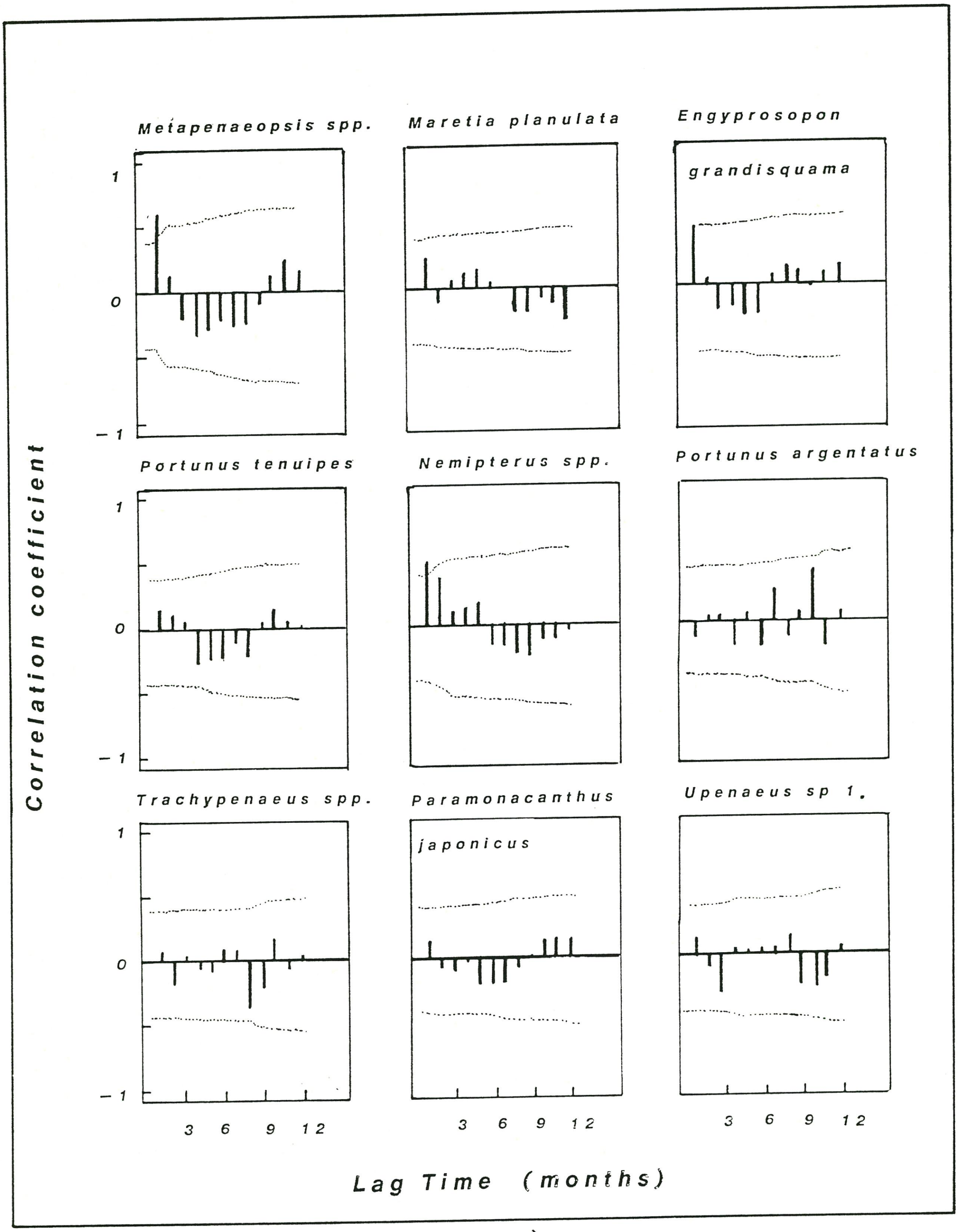

Figure 4. Auto correlations (95% confidence limits as ...) with 1 to 12 month lags in abundance for 10 most abundant species

Abundance by Taxonomic Class

By-catch from 1986 bycatch samples was dominated by Malacostraca (Decapoda) and Osteichthyes (bony fish)(Table 5). Whilst the relative proportions of by-catch from these two groups varied considerably between the 1985 and 1986 by-catch samples, the between-year variation in faunal classification was not statistically significant (X^2_{10}, P>0.10).

Table 5. Abundance (%) of major taxonomic groups.

Phylum	Class	Abundance of Individuals (from subsample data) 1985	1986
Chordata	Ascidiacea	0.6	0.3
	Osteichthyes	40.5	34.5
Crustacea	Malacostraca	38.7	54.1
Echinodermata	Crinoidea	<0.1	<0.1
	Asteroidea	0.6	0.3
	Ophiuroidea	<0.1	<0.1
	Echinoidea	15.9	6.7
	Holothuroidea	0.2	0.2
Mollusca	Gastropoda	<0.1	<0.1
	Pelecypoda	3.2	3.0
	Cephalopoda	0.7	0.9

By-catch Weight and species Richness: Site and Temporal Effects

Runs analyses indicated that by-catch weight and species richness were not subject to consistent seasonal trends (by-catch weight-9 runs, 11 d.f., $p > 0.10$, number of species-6 runs, 11 d.f., $p > 0.10$) (Figure 5).

By-catch weight was then considered in terms of seasonal and site effects using two way ANOVA. Both column (time) and row (site) effects were significant ($F = 2.95$, 11 df, $p < 0.01$; $F = 5.37$, 10 df, $p < 0.01$ respectively). The number of species present in subsamples was not significantly affected by time, but was significantly affected by site effects ($F = 1.19$, 11 df, $p > 0.05$; $F = 13.83$, 10 df, $p < 0.01$ respectively). The most conspicuous variation in species numbers between sites was the relatively low average number of species recorded at site 1, the site nearest the shore (Figure 6).

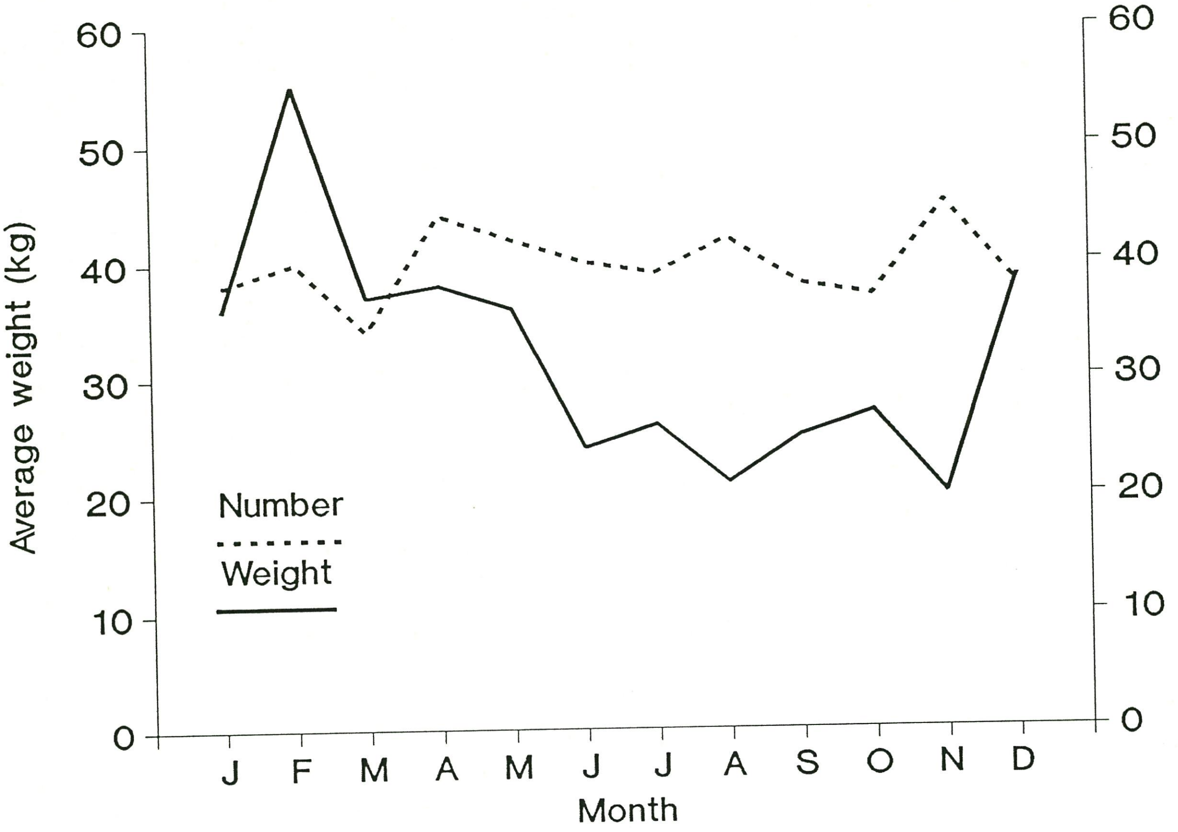

Figure 5. Average weight and number of species per sample per month in 1986

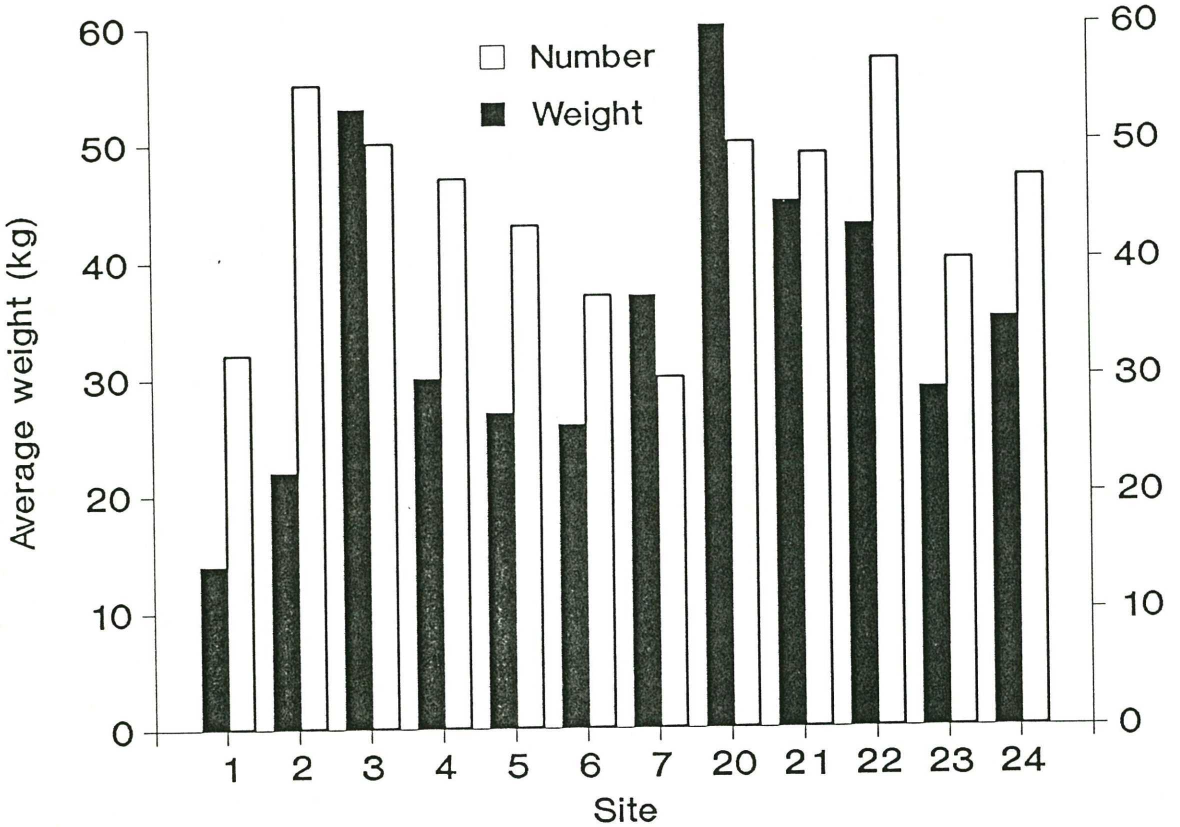

Figure 6. Average weight and average number of species taken at each sample site in 1986

Numerical Classification

All 133 samples taken in 1986 were aggregated on the basis of their faunal similarity using numerical classification. The associations so formed were examined using dendrograms. The samples which aggregated at a dissimilarity level giving rise to eight groups of aggregations (an arbitrary figure) (Figure 7) were examined for common site or temporal characteristics. The eight aggregations have been set out in a matrix format in Table 6. Each group consists of samples from given months and sites. The time/site entities which aggregated into groups have been displayed by both month and site number in the table.

Two of the 'groups' so formed were singleton samples which were clear outliers to the remainder of the data. Groups 3 and 4 each came from a single sampling site (sites 1 and 2 respectively), indicative that these sites possessed faunas which were consistently dissimilar to other sites through the year.

Groups 5 to 8 were more complex. Group 5 consisted predominantly of samples from sites 3 and 24, which were both mid Great Barrier Reef Lagoon sites. Group 6 included a number of samples from 4 and 23, which were both mid Great Barrier Reef Lagoon sites in the terminology of Watson and Goeden (1989), but closer to reefs than 3 and 24. Group 6 also included a series of samples from the month of November, which came from mid Lagoon and near-reef sites. Group 7 included diverse sites and times. The group of samples in this group from the months May - August may indicate a winter fauna associated with mid Lagoon and near-reef sites, but the picture is confounded by site effects. The samples from Group 8 were almost entirely from sites 5, 21 and 22, which were near-reef, deep water sites. More samples in Group 8 came from the early part of the year than from the latter half, but again seasonal effects were not strong.

While some seasonal effects were evident in this summary, the dominant factor associated with sample aggregations appeared to be site effects, rather than those attributable to season.

Table 6. Site and temporal characteristics of eight entity aggregations from all samples taken in 1986.

Month	J	F	M	A	M	J	J	A	S	O	N	D
Group 1												
Site 7					*							
Group 2												
Site 3												*
Group 3												
Site 1	*	*	*	*	*	*	*	*	*	*	*	*
Group 4												
Site 2	*	*	*	*	*	*	*	*		*	*	*
Group 5												
Site 3		*	*	*	*	*	*	*	*	*	*	
22							*					
23	*					*				*		
24	*	*	*	*	*	*	*		*			
Group 6												
Site 3	*											
4	*	*	*	*	*	*			*		*	*
6	*	*		*		*					*	
7											*	
20		*				*					*	
21											*	
22								*		*		
23		*	*	*	*		*	*	*		*	
24								*		*	*	*
Group 7												
Site 4							*	*		*		
5						*	*			*		
6			*		*		*	*		*		*
7							*	*		*		
20	*		*	*	*				*			
21												*
Group 8												
Site 5	*	*	*	*	*			*	*	*		*
6									*			
20							*	*		*		
21	*	*	*	*	*	*	*	*	*	*		
22	*	*	*	*	*				*			*
23												*

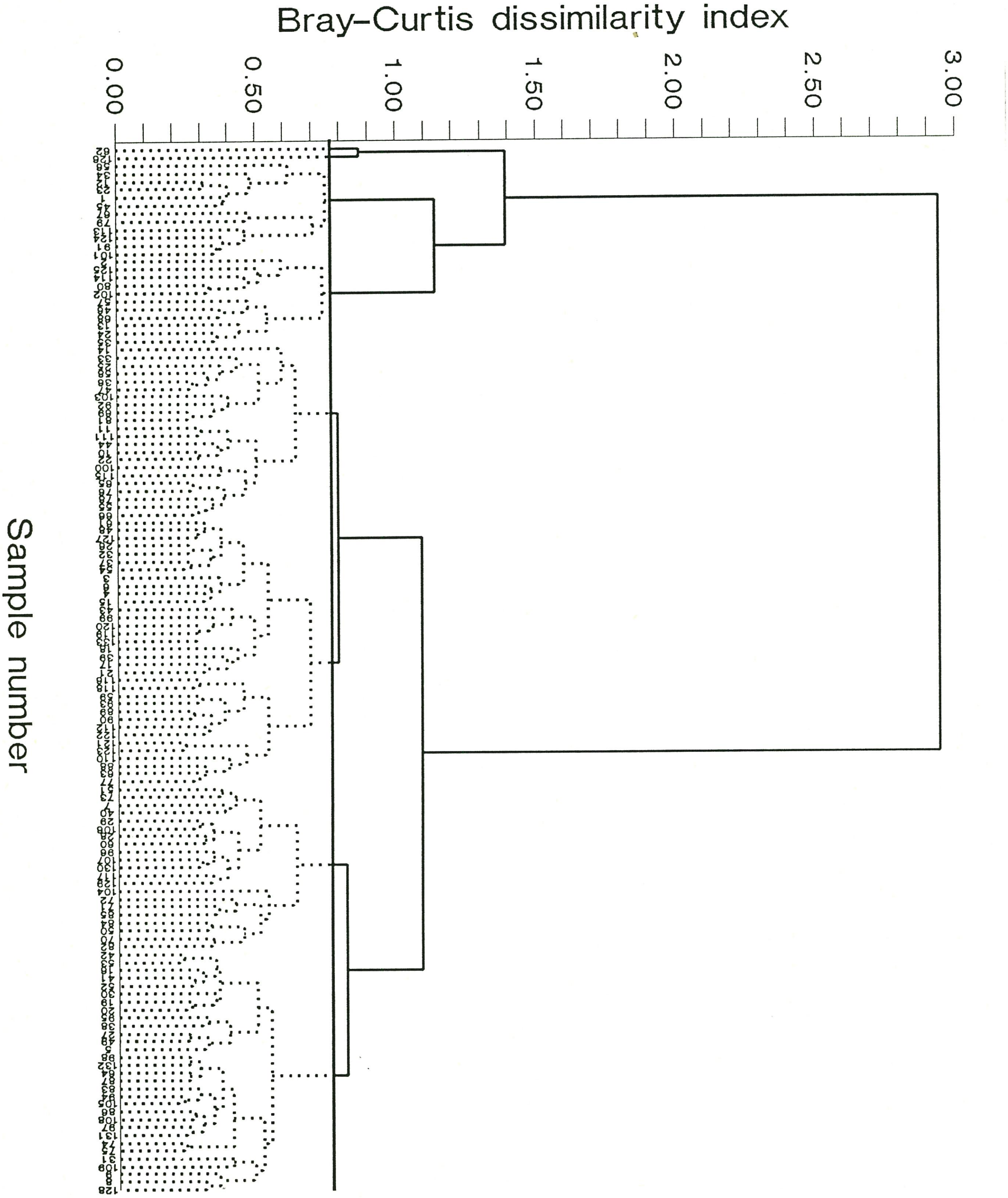

Figure 7. Site associations created by grouping all 1986 samples. An arbitrary cut-off point (0.77 on Bray-Curtis dissimilarity index) was used to create 8 site groupings

Temporal associations

Seven of the 24 sites sampled in 1985-6 (sites 1-6 and 20) were sampled with two or fewer lost samples in the 24 months of sampling. Data on log transformed species abundances from these seven sites were grouped by month and examined for observable temporal associations on the basis of faunal dissimilarity. Results are summarised in Figures 8 and 9. There were two conspicuous outliers viz. time groups 5 (May 1985) and 1+2 (January-February 1985). The third group of entities include a set of 5 months, all of which grouped into February-April, thus including both 1985 and 1986 samples. A group of samples taken during the latter half of 1986 (months 18-24) consisted of two components. These were the subsets (months 18,21,23) and (months 19,20,22,24). The remaining samples formed a more heterogenous group which included June 1985-January 1986, and May 1986.

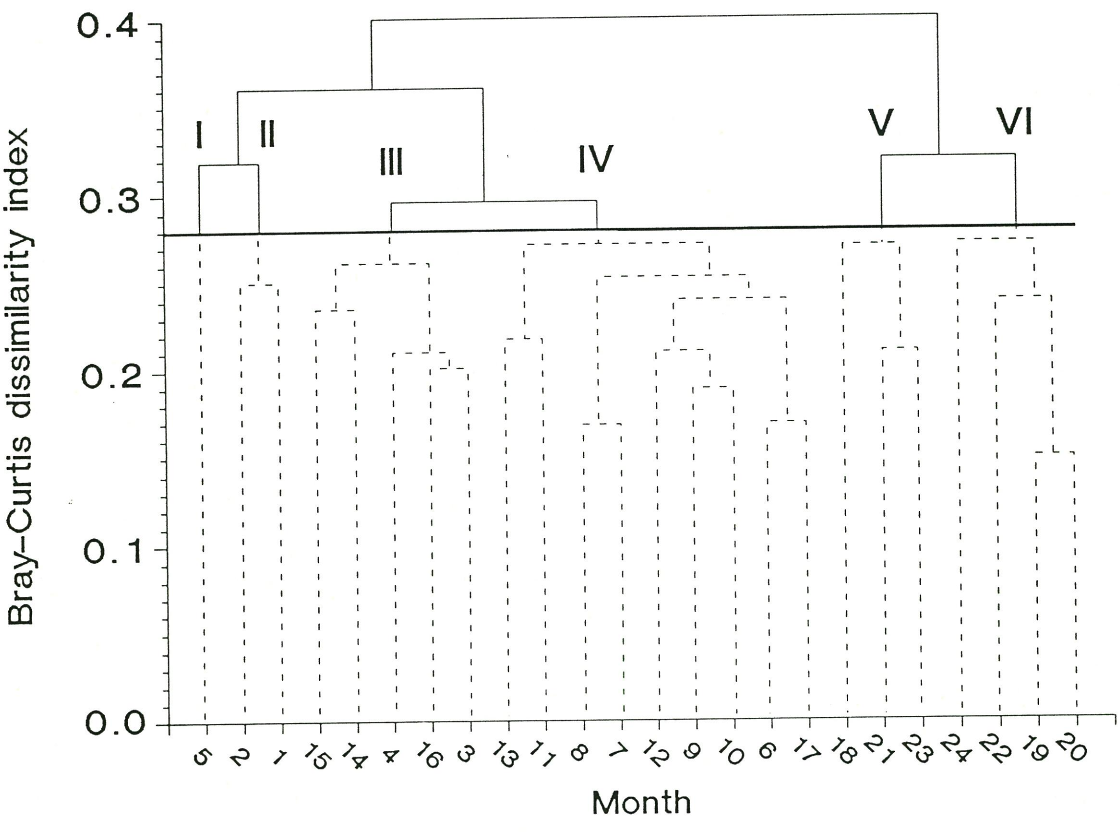

Figure 8. Temporal aggregation of data from the 24 months sample set, using data from sites 1 to 6 and 20

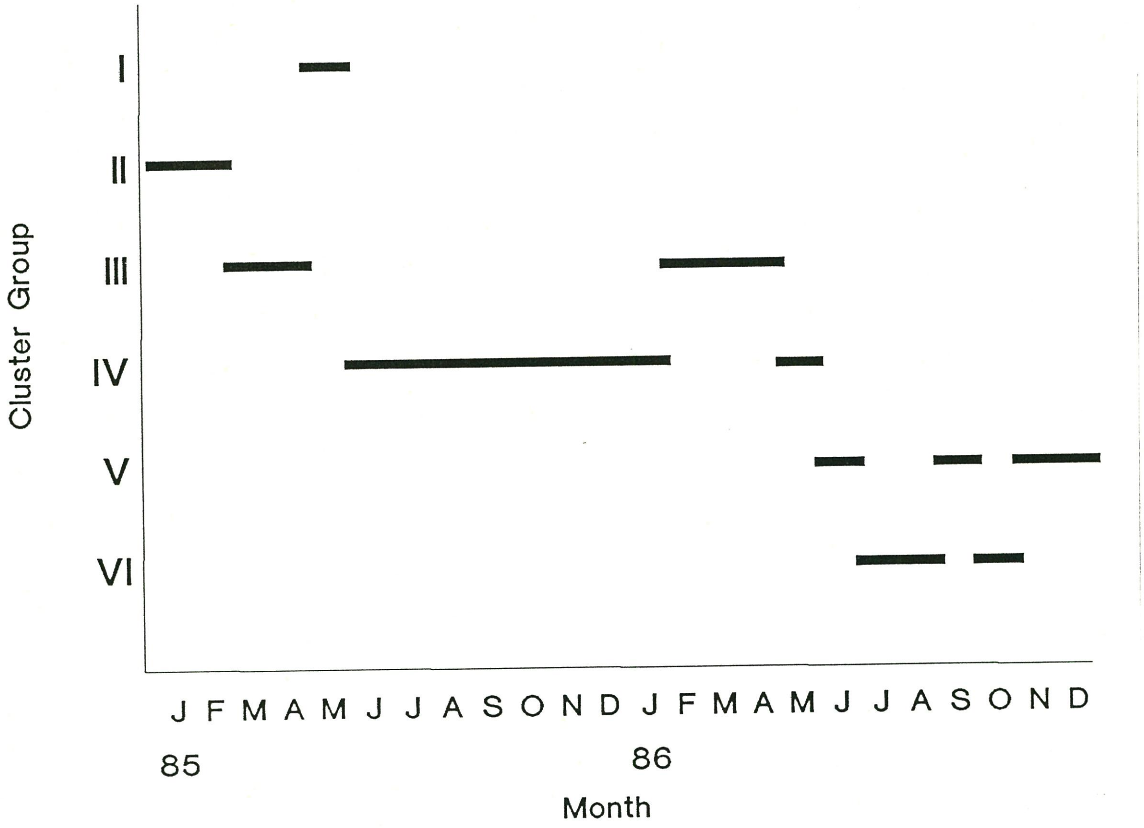

Figure 9. Groupings of time entities, based upon monthly samples from sites 1 to 6 and 20

Species which were responsible for maximum heterogeneity in temporal groupings have been listed in Table 7. Changes in abundance and species composition of the Bothidae (Osteichthyes) over time were responsible for appreciable components of differences in temporal associations, particularly with respect to the divergence between the late 1986 group and other time entities.

Some of the temporal groupings, such as the March-April associations for 1985-6, made conceptual sense, and indicated that there may have been some constancy of faunas in successive annual seasons. But the substantial heterogeneity between, for example, late 1985 and late 1986 indicates that there was as much likelihood of substantial changes in the trawlable faunal communities of equivalent seasons in successive years as there was of consistent faunal associations from year to year.

Table 7. Species associated with maximum divergence in temporal groupings.

Species	June-Dec. 1986	Temporal Group All other months	Jan.-Feb.,May 1985
Pseudorhombus duplicellatus	+++	+	
P. diplospilus	+++	+++	
P. spinosus	+++	+++	
P. jenynsii	+	+++	
Metapenaeopsis palmensis	-	+++	
Inegocia isacanthus	+++	+++	
Dactyloptena orientalis		+	+++
Maretia planulata		+++	+++
Tragulichthyes jaculiferus		++	+++
Minous versicolor		+	+++
Saurida micropectoralis		+++	+++
Synodus similis		+++	+++

Abundance - = 0, + = ln(.1)-ln(.99), ++ = ln(1)-ln(1.99), +++ = >ln(2)

Site Associations

The relationship between sample sites was considered as a function of their faunal associations, using numerical classification. Numerical classification analysis was carried out on each monthly data set from 1986, using sites as the entities being examined. The analysed data were examined at the third dichotomy in each month's dendrogram (Figure 10), thus giving four groups of sites in each month. The four groups were then examined to see how frequently a particular site grouped with other sites at that level of dissimilarity. For example, site 6 grouped with site 22 on eight out of the ten times both sites were mutually sampled. Site 4 grouped with site 20 on three of the eleven times both sites were sampled in the one month.

The results of this analysis have been summarised in Table 8. The two inshore sites (1 and 2) almost invariably failed to group with other sites. The inshore sites split from each other and from all other sites at a high level of dissimilarity, indicative that the fauna of the sites was very different both from each other and from all other sites. The remaining site associations did not give such clear cut results. The near-reef / deeper water sites 5, 6, 7, 21, and 22 were frequently grouped together, indicating that there may have been a consistent difference between these and other sites. But site 23, a near-reef, deeper site, did not group with these sites consistently. The mid Lagoon sites 3, 4, and 24 grouped together in the majority of months. Site 20, also a mid Lagoon site, rarely occurred in the same group of sites. While there was some evidence of fauna differences between near-reef and mid Great Barrier Reef Lagoon sites, the segregation was not as clear as the inshore to offshore fauna separation, which is consistent with the findings of Watson and Goeden (1989).

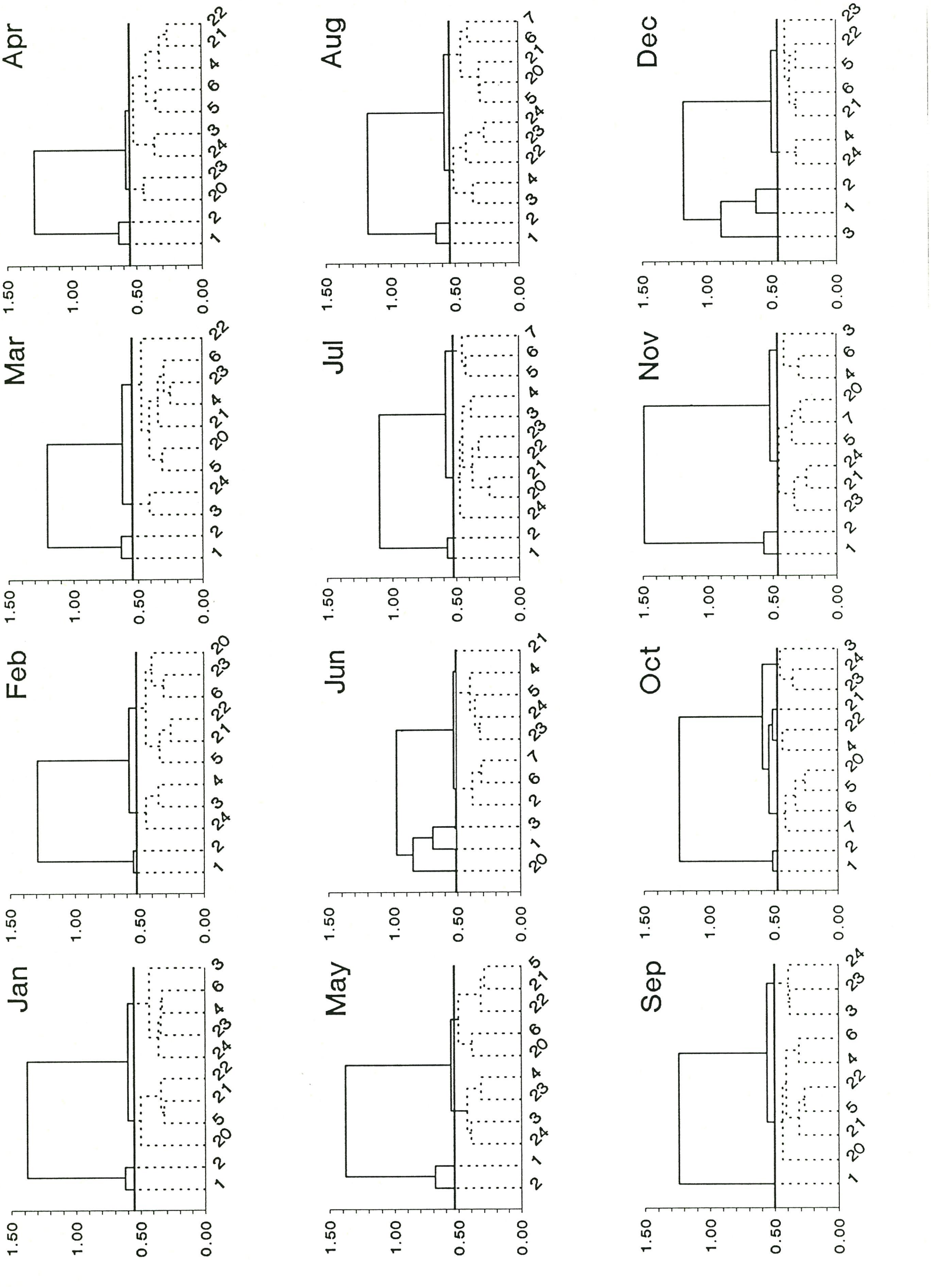

Figure 10. Site associations from 1986 monthly numerical classification analyses

Table 7. Frequency of site associations (number of times grouped/number of times sites were sampled in one month) at the third dichotomy of monthly numerical analysis dendrograms.

Site	1	2	3	4	5	6	7	20	21	22	23	24
1												
2	0											
3	0	0										
4	0	.09	.58									
5	0	.09	.08	.50								
6	0	.09	.25	.67	.83							
7	0	.20	0	.40	1.0	.80						
20	0	0	.09	.27	.64	.45	.60					
21	0	.09	.17	.58	.91	.75	.80	.72				
22	0	0	.30	.70	.90	.70	.33	.67	.90			
23	0	.09	.50	.58	.42	.41	.40	.55	.50	.50		
24	0	.09	.75	.67	.33	.33	.40	.18	.42	.40	.75	

Comparison between near-reef and reefal fauna

The existence of a faunal gradation or zonation from the immediate vicinity of coral reefs to off-reef areas was examined by examining monthly dendrograms at low levels of faunal dissimilarity. The existence of a specific fauna associated with the reef perimeter require that either sites 5, 22, and 23 show some evidence of similarity, or that site 22 (the very near-reef site) should have unique faunal characteristics. In four of the monthly data sets, sites 5, 21 and 22 aggregated as the most similar sites. Site 22 grouped with sites 21 and 4 in a further two months, and with 23 in three months. While there was some indication that the fauna of sites in very near proximity to coral reefs was differentiated from that further from reefs, the differences were by no means clear cut, and certainly not absolute. The species composition of all samples taken from site 22 was accumulated and summarised. Osteichthyes were then extracted from the summary. Of the 59 species which occurred in site 22 samples, 16 appear in Russell's (1983) checklist of fish from the Capricornia section of the Great Barrier Reef Marine Park. Of these, 10 of these are specifically mentioned as being taken by trawl (Table 9). The 59 species of fish recorded in (subsampled) data from site 22 came from 27 families. Families which included the largest number of species (Nemipteridae, Scorpaenidae, Platycephalidae and Bothidae, 5 to 6 species each) are poorly represented in the reefal environment (Russell 1983). There is no evidence to suggest that the fauna in very near proximity to the reef is in some way intermediate between true reef associated fauna and the inter-reef and mid Great Barrier Reef fauna described in an earlier report (Dredge 1988).

Table 9. Species common to site 22 (near-reef) and Russell's(1983) checklist of fish from the Capricornia-Bunker section of the Great Barrier Reef Marine Park.

Species	Family
*Synodus similis**	Synodontidae
Sargocentron rubrum	Holocentridae
Fistularia commersoni	Fistulariidae
*Erosa erosa**	Scorpaenidae
*Lepidotrigla calodactyla**	Triglidae
*Dactyloptena orientalis**	Dactylopteridae
*Priacanthus macracanthus**	Priacanthidae
*Nemipterus furcosus**	Nemipteridae
Lethrinus nematacanthus	Lethrinidae
Pristotis jerdoni	Pomacentridae
Arnoglossus intermedius	Bothidae
*Pseudorhombus dupliciocellatus**	
*Pseudorhombus spinosus**	
*Paramonacanthus japonicus**	Monocanthidae
Lagocephalus scleratus	Tetradontidae
*Torquigener tuberculiferus**	

* Recorded by Russell(1983) as being taken by trawl in the Capricorn-Bunker area.

Site segregation from 1986 samples

Data from the 11 stations sampled consistently during 1986 were aggregated and analysed for site associations on an annual basis (Figure 11). The inshore sites (1 and 2) were shown as clear outliers both to each other and,at a higher level of dissimilarity, to all other sites. Sites 5, 6 and 23 grouped at the second dichotomy in the dendrogram. The fact that these were the three deepest sites sampled may not be coincidental. Site 22, the site nearest a reef environment, segregated from other near-reef and mid-Lagoonal sites at a relatively high level of dissimilarity, but was most closely related to sites 3, 20, 24, 21 and 4 on the basis of faunal composition. These sites cover a mixture of near-reef and mid-Lagoon locations. The difference between fauna at site 22 and other sites may be due, in part, to the loss of two samples from site 22 during the year.

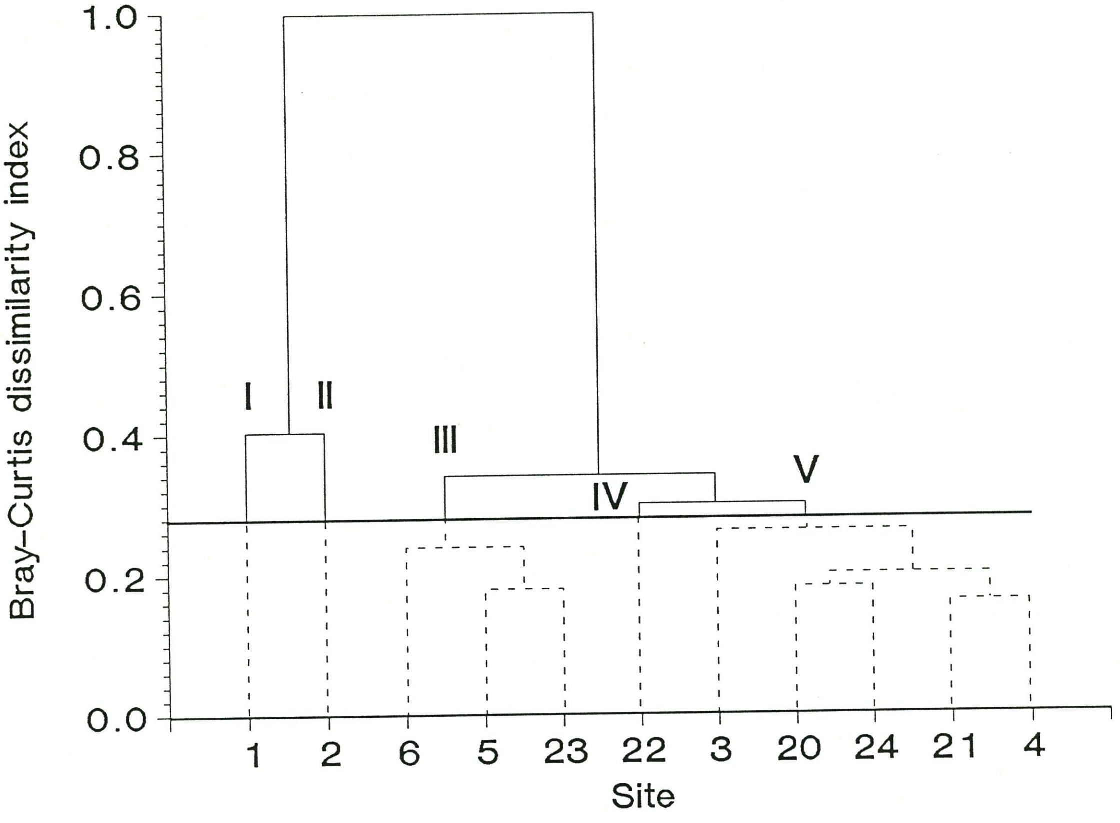

Figure 11. Site associations based upon numerical classification from all 1986 data

DISCUSSION AND CONCLUSION

The report, and its associated publications (Jones and Derbyshire 1988, Dredge 1988, Watson and Goeden 1989, Watson *et al.* 1990) give a comprehensive check list of trawlable demersal fauna from the continental shelf off central Queensland. Numerical classification has been used to delineate between spatially and temporally segregated faunas associations.

In an earlier report, recognisable faunal associations in trawl by-catch between 18°S and 19°30'S were described from samples taken in 1985 (Dredge 1988). The by-catch was dominated by Osteichthyes and decapod Crustacea. In 1986, decapods and bony fish were again the dominant organisms, but there was an increase in the relative abundance of decapods relative to fish. There is no obvious reason why this change should have occurred.

The Osteichthyes from trawl by-catch were numerically dominated by the Nemipteridae and a number of families of flatfish, including Bothidae, Pleuronectidae and Platycephalidae. These families were also the dominant families taken in 1985 samples and the species which were most abundant in 1985 were again dominant in 1986. Both the species and families which were most abundant in trawl by-catch were not characteristic of the coral reef fauna.

The absence of equivalent structured studies on trawl by-catch make meaningful geographic comparison difficult. Cannon *et al.* (1987) demonstrated the existence of inshore and offshore or near-reef faunal assemblages over much of the Queensland east coast. Rainer and Munro (1982) described inshore, offshore and transitional faunal communities in the Gulf of Carpentaria prior to the existence of trawl fisheries in that area. They list an offshore fish faunal with a number of families and genera common to the Great Barrier Reef Lagoon, but an inshore fish fauna which appears to vary considerably from that described in the present report. Ramm *et al.*(1990) have demonstrated faunal variation in trawl by-catch both as a function of depth and geographic location off the northern Australian coastline, with marked differences between fauna from the western and eastern sectors. Rainer (1984) and Poiner and Harris (1986) inferred that trawling had affected the species composition, but not the geographic spacing of site-groups from the Gulf of Carpentaria. As all samples taken in the present study were collected well after the commencement of an intensive trawl fishery (Dredge 1988), it is not possible to comment on faunal changes that may have occurred as a consequence of this trawling. Thollot and Kulbicki (1988) described faunal composition from mangrove, soft bottom and coral reefs in New Caledonia and showed that a higher proportion of species were common to the reef and soft bottom environments than was the case in this study. There may be some significance that the soft bottom area studied by Thollot and Kulbicki (1988) had not been subjected to trawling, and thus may have not lost the three dimensional structure of sponges and other epibiota which is subject to damage by trawling (Sainsbury 1988).

The stability of temporal groupings was considered by Rainer (1984) to be a significant factor in the composition of by-catch fauna from Gulf of Carpentaria. This is in contrast with the present findings on the relative significance of location/ depth/ substrate composition and temporal variation in association with bycatch composition.

A number of authors have proposed inner and mid-shelf faunal zones, based on marked differences between inshore and mid-shelf species compositions in a range of taxonomic groups (Done 1982, Dineson 1983, Williams 1983, Birtles and Arnold 1988 Williams et al. 1988). Little was known of temporal variation in the faunas responsible for this zonation, or of year to year stability of zonation. The precise nature of variation within the mid-shelf zone communities described by Watson and Goeden (1989) had not been studied in detail, and the nature of transition from true reef associated fauna to off-reef fauna was undescribed.

Analysis of data collected in 1985 showed that recognisable faunal associations occurred in the by-catch. An inshore or coastal fauna having species and abundance characteristics greatly different to those from areas further offshore was a consistent feature in by-catch analysis. The same difference has been observed in the epibenthic fauna (Arnold et Birtles 1988) and in other specific taxonomic groups. In the offshore environment, the by-catch fauna formed a further two groups, which were associated with near-reef and mid Great Barrier Reef sample sites. The fauna was dynamic, with different species dominating the fauna as the year progressed. This pattern was repeated in 1986. The coastal and inshore sites were consistently different to each other and to offshore sites in terms of faunal composition. There was a less marked, and less consistent difference between faunas of mid-Great Barrier Reef Lagoon sites and near-reef sites. Some sample sites did not fall into the near-reef or mid Lagoonal faunal groups despite their being at near-reef or mid Lagoonal locations. However, the basic zonation remained stable between seasons and years.

The nature of faunal transition from the perimeter of a coral reef to the middle of the Great Barrier Reef Lagoon was examined in a monthly sampling which extended over 12 months. While summarised results indicated that differences between near-reef and off-reef faunas did exist, examination of monthly data sets from sites indicated that the differentiation of faunas was not absolute. Numerical classification showed that in some, but not all cases, fauna from near-reef, deep water sites was in some way differentiated from off-reef sites. There appeared to be a more marked difference in the fauna of the reef proper and that of near-by soft bottoms, although was overlap between a small number of fish species.

The abundance of numerically dominant species in the 1985 and 1986 sets of samples was examined, but there was inadequate data to detect meaningful annual cycles in these species. The nature of faunal transition over a two year period was examined after by-catch data from six sites sampled consistently in 1985-86 were amalgamated into a monthly series extending over a two year period. The resulting temporal associations made conceptual sense in some cases, such as the year to year associations of March-April in 1985 and 1986. The marked difference between fauna taken from late 1986 samples and other times, and the obvious absence of successive seasonal patterns between late 1985 and late 1986 suggests that such annual patterns may not be a persistent feature of trawlable faunas in the Great Barrier Reef Lagoon. This observation contrasts with Rainer's (1984) findings that annual variability was less marked than seasonal variation in Gulf of Carpentaria by-catch.

Data in this study has been examined largely on the basis of summaries from the raw data or using numerical classification. Numerical classification was used to describe the relationships of fauna over time and space because there are no alternative techniques for making conceptual sense of an extremely complex data matrix. With the benefit of hindsight, it is easy to point out some of the deficiencies of this type of analysis. A series of alternative techniques for calculating diversity indices and association strategies have been developed, and the literature dealing with theoretical concepts of numerical classification is growing rapidly. Selection criteria chosen for particular diversity indices and aggregating strategies may influence results considerably (Clifford and Stephenson 1975, pp 140-142). Data transformation to suppress dominant species is a standard procedure in numerical classification, and is carried out in a more or less arbitrary manner. The consequent loss or distortion of information associated with transformation is only now being dealt with in specialist literature. In very extensive data bases, further subjective decisions concerning the need to contract the size of these data bases are needed. For example, in the present study, only 200 of the 475 entities (species) could be handled by the program used for data analysis. An arbitrary decision to drop rare or sporadic species may have had important consequences in the analytical results. Perhaps one of the most disturbing features of the analysis was the inability to apply convention statistical theory to results. This lead to results from which inferences could be drawn, rather than hypotheses which could be tested.

Recent developments in this field will result in some of the deficiencies associated with numerical classification being overcome. There are recent developments in treatments of information trees and matrices developed in numerical classification which facilitate statistical treatment of data and allow meaningful comparison between groups and entities. The concepts involved in this field are complex, and a multi-disciplinary approach to this form of analysis may be required.

A re-examination of the present data (Watson *et al.* 1990) has shown that the most recent analytical packages, such as PATN, offer more precise methods of examining databases such as the one which has been developed in the current programme. A particularly interesting feature of this re-examination was the close correlation between grouping of entities using the whole database and using a very limited number of 'indicator' species. As the difficulties and costs associated with holistic studies are considerable, future work should be concentrated on representative species which could be used as indicators for the remainder of the communities.

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APPENDIX 1.

Checklist of the 477 species taken by trawl in 1985-86 and rank of numerical abundance for the 200 taxa used in numerical classification analyses.

P. MOLLUSCA
C. GASTROPODA
SC.PROSOBRANCHIA
O. ARCHEOGASTROPODA
F. FISSURELLIDAE
Scutus unguis
O. MESOGASTROPODA
F. XENOPHORIDAE
Xenophora sp.1...............103
F. STROMBIDAE
Strombus dilatatus
Strombus vittatus
Terebellum terebellum
F. CYMATIIDAE
Distorsio reticulata
F. BURSIDAE
Bursa sp.1
F. CASSIDAE
Phalium bisulcatum
Phalium glabratum angasi
F. TONNIDAE
Tonna cerevisina
Tonna tetracotula
Tonna sp.1
F. CYPRAEIDAE
Cypraea sp.1
F. OVULIDAE
Volva volva
F. NATACIDAE
Polinices sp.1
O. NEOGASTROPODA
F. MURICIDAE
Bedeva c.f. paivae
Chicoreus banksii
Chicoreus sp.1
Murex nigrospinosus
Rapana rapiformis
F. FASCIOLARIIDAE
Pleuroploca sp.1
F. HARPIDAE
Harpa articularis
F. VOLUTIDAE
Melo sp.1
Volutoconus grossi mcmichaeli
F. VASIDAE
Tudicula armigera
SC. OPISTOBRANCHIA
O. ANASPIDIA
F. APLYSIIDAE
Aplysia sp.1 160
Dolabella auriculana
O.NOTASPIDIA
F. PLEUROBRANCHIDAE
Pleurobranchidae sp.1
O. NUDIBRANCHIA
F. DORIDIDAE
Dorididae sp.1
F. CHROMODORIDIDAE
Ceratosoma cornigerum
F. ARMINIDAE

Armina sp.1
C. BIVALVIA
SC. LAMELLIBRANCHIA
O. TOXODONTA
F. ARCIDAE
Opularca tenella
O. ANISOMYARIA
F. PECTINIDAE
Mimichlamys leopardus.........103
Chlamys sp.1
F. AMUSIIDAE
Amusium balloti................10
Amusium pleuronectes...........44
F. SPONDYLIDAE
Spondylus wrightianus
O. HETERODONTA
F. CARDIIDAE
Fragum hemicardium
F. TELLINIDAE
Tellinidae sp.1
C. CEPHALOPODA
SC. COLEOIDEA
O. SEPIOIDEA
F. SEPIIDAE
Metasepia pfefferi
Sepia elliptica }............18
Sepia plangon }
Sepiadarium kochi
F. SEPIOLIDAE
Euprymna sp.1
Sepioloidea lineolata

O. TEUTHOIDEA
F. LOLIGINIDAE
Loligo chinensis.............118
Loligo sp.1
Loliolus sp.1
O. OCTOPODA
F. OCTOPODIDAE
Octopus spp.
P. CRUSTACEA
C. MALACOSTRACA
SC. HOPLOCARIDA
O. STOMATOPODA
F. GONODACTYLIDAE
Gonodactylus graphurus........149
F. HARPIOSQUILLIDAE
Harpiosquilla harpax
Harpiosquilla melanoura
F. SQUILLIDAE
Squilla anomala...............118
Squilla costata
Squilla multicarinata.........122
Squilla nepa
Squilla quinquedentata
Squilla woodmasoni............117
Squilla sp.1
Squilla sp.2
SC. PERACARDIA
O. ISOPODA

Calcipila cornuta
Creniola saurida

SC. EUCARIDA

O. DECAPODA

F. SOLENOCERIDAE

Solenocera australiana
Solenocera sp.1...............107
Solenocera sp.2

F. PENAEIDAE

Atypopenaeus stenodactylus
Metapenaeopsis lamellata.......58
Metapenaeopsis mogiensis }......1
Metapenaeopsis rosea }
Metapenaeopsis palmensis.......43

Metapenaeus endeavouri.........39
Metapenaeus ensis.............25
Parapenaeopsis cornuta
Penaeus canaliculatus
Penaeus esculentus............101
Penaeus latisulcatus...........22
Penaeus longistylus............11
Penaeus merguiensis
Penaeus monodon
Penaeus semisulcatus...........94
Trachypenaeus anchoralis }
Trachypenaeus curvirostris }....3
Trachypenaeus granulosus }
Trachypenaeus fulvus }

F. SICYONIDAE

Sicyonia cristata..............40

F. ALPHIIDAE

Alpheus sp.1

F. PALINURIDAE

Panulirus ornatus

F. SCYLLARIDAE

Scyllarus demani...............98
Scyllarus rugosus..............82
Scyllarus martensii
Thenus orientalis..............53
Thenus sp.1

F. PAGURIDAE

Paguridae spp.

F. GALATHEIDAE

Galatheidae sp.1

F. DROMIIDAE

Dromidia sp.1
Dromidiopsis australiensis
Dromidiopsis edwardsi

F. DORIPPIDAE

Dorippe frascone

F. LEUCOSIIDAE

Arcania elongata
Ixa inermis

F. MAJIDAE

Austrolobinia capricornesis
Hyastenus campbelli 181
Hyastenus diacanthus..........166
Naxoides taurus
Phalangipus australiensis.....151

F. PARTHENOPIDAE
- Cryptopoida sp.1
- Parthenope contrarius 173
- Parthenope longimanus 156
- Zebrida adamsi

F. CORYSTIDAE
- Jonas luteanus
- Notopus dorsipes

F. PORTUNIDAE
- Charybdis anisodon
- Charybdis callianassa
- Charybdis cruciata
- Charybdis jaubertensis.........91
- Charybdis natator.............143
- Charybdis truncata.............12
- Lupocyclus philippinesis
- Lupocyclus rotundatus..........90
- Podophthalmus vigil
- Portunus argentatus.............8
- Portunus gracilimanus..........73
- Portunus orbitosinus..........134
- Portunus pelagicus.............67
- Portunus rubromarginatus.......13
- Portunus sanguinolentus
- Portunus tenuipes...............2
- Portunus tuberculosis
- Thalamita parvidens
- Thalamita sima
- Thalamita sp.1

F. XANTHIDAE
- Actumnus pugilator
- Demania macnielli
- Demania c.f. splendida
- Eucrate dorsalis
- Liagore rubromaculata
- Neoxanthias michelae
- Pilumnus ?longicornis
- Pilumnus nigrispinifer
- Thacanophrys longispinus
- Trichia dromiaeformis

P. ECHINODERMATA

C. CRINOIDEA

SC. ARTICULATA

O. COMATULIDA

F. COMASTERIDAE
- Comanthina schlegeli

F. ASTEROMETRIDAE
- Pterometra venusta

Comatulid spp.....................66

C. ASTEROIDEA

O. PHANEROZONIA

F. LUIDIIDAE
- Luiidia maculata..............161

F. ASTROPECTINIDAE
- Astropecten zebra............116

F. GONIASTERIDAE
- Anthenea sp.1
- Goniasteridae sp.1
- Goniodiscaster australiae
- Iconaster longimanus

Iconaster sp.1
Stellaster equestris...........95
F. ORIASTERIDAE
Asterodiscus elegans
Culcita novaeguinea
Pentaceraster gracilis........170
Pentaceraster regulus
Pentaceraster sp.1
Poraster superbus
F. OPHIDIASTERIDAE
Nardoa sp.1
Tamaria fusca
Tamaria megaloplax
F. METRODIRIDAE
Metrodira subulata............104
O. SPINULOSIDA
F. ACANTHASTERIDAE
Acanthaster brevispinus
Acanthaster planci
F. PTERASTERIDAE
Euretaster insignis
C. OPHIUROIDEA
O. PHRYNOPHIURIDA
F. EURYALIDAE
Euryale aspera................121
O. GNATHOPHIURIDA
F. OPHIOTRICHIDAE
Ophiomaza cacaotica...........178
Ophiothrix martensi australis
O. CHILOPHIURIDA
F. OPHIODERMATIDAE
Ophiarachnella gorgonia
Ophiochasma stellatum........131
Ophiuroid spp................144
C. ECHINOIDEA
O. CIDAROIDA
F. CIDARIDAE
Prionocidaris bispinosa.......97
O. CENTRECHINOIDA
F. DIADEMATIDAE
Chaetodiadema granulatum......68
F. TEMNOPLEURIDAE
Salmaciella dusumieri........106
Temnotrema bothryoides.......108
Temnotrema sp.1 }............157
Temnotrema spp }
O. EXOCYCLOIDA
F. LAGANIDAE
Peronella leseuri............142
Peronella orbicularis........140
F. SPATANGIDAE
Maretia planulata..............4
C. HOLOTHUROIDEA
O. DENDROCHIROTIDA
F. CUCUMARIIDAE
Pentacta anceps
Pentacta crassa
Pentacta quadrangularis
Pseudoclolochirus axiologus
F. PHYLLOPHORIDAE

Actinocucumis typicus
Phyllophorus (Urodemella) holothuroides
O. ASPIDOCHIROTIDA
F. HOLOTHURIIDAE
Holothurian spp................60
Actinopyga echinites
Bohadschia sp.1
Holothuria (Mertensiothuria) sp.1
Holothuria (Metriatyla) ocellata
Holothuria (Metriatyla) martensi
F. STICHOPODIDAE
Stichopus variegatus
P. CHORDATA
C. ASCIDIACEA
Zooanthus sp.1................24
Ascidian spp.................37
C. CHONDRICHTHYES
SC. ELASMOBRANCHI
O. SELACHII
F. ORECTOLOBIDAE
Orectolobus sp.1
F. HEMISCYLIDAE
Chiloscyllium punctatum
O. BATOIDEA
F. RHYNCHOBATIDAE
Rhynchobatus sp.1
F. DASYATIDAE
Dasyatis kuhlii.............145
Himantura sp.1
C. OSTEICHTHYES
SC. ACTINOPTERYGEI
O. CLUPEIFORMES
F. CLUPEIDAE
Amblygaster sirm
Sardinella fimbriata ? (possibly S. albella)
F. ENGRAULIDAE
Thryssa hamiltonii
Thryssa setirostris
Stolephorus (Encrasicholina) devisi
O. ANGUILLIFORMES
F. MURAENIDAE
Gymnothorax reticularis
Gymnothorax undulatus
F. MURAENESCOCIDAE
Muraenosox bagio
Muraenosox cinereus
F. NETTASTOMATIDAE
Nettastomatidae sp.1
O. SILURIFORMES
F. PLOTOSIDAE
Euristhmus lepturus
Euristhmus nudiceps...........78
Plotosus anguillaris.........113
O. MYCTOPHIFORMES
F. SYNODONTIDAE
Saurida micropectoralis
Saurida tumbil................88
Saurida undosquamis...........20
Saurida sp.1 (juvenile)
Synodus sageneus.............85

Synodus similis...............52
Synodus sp.1
Trachinocephalus myops........26

O. BATRACHOIDIFORMES
F. BATRACHOIDIDAE
Batrachomoeus trispinosus....158

O. LOPHIIFORMES
F. ANTENNARIIDAE
Antennarius commersoni
Antennarius hispidus.........147
Antennarius nummifer
Antennarius striatus
Antennarius sp
Tathicarpus butleri..........102

F. TETRABRACHIIDAE
Tetrabrachium ocellatum

O. OPHIDIIFORMES
F. OPHIDIIDAE
Sirembo jerdoni..............154
Sirembo imberbis

F. CARAPIDAE
Carapus c.f. homei
Jordanicus gracilis

O. GADIFORMES
F. BREGMACEROTIDAE
Bregmaceros c.f. nectabanus

O. BELONIFORMES
F. BELONIDAE
?Ablennes hians (juv)

F. EXOCOETIDAE
Cypselurus sp.1

F. HEMIRAMPHIDAE
Euleptorhamphus viridis

O. BERYCIFORMES
F. HOLOCENTRIDAE
Sargocentron rubrum..........146

O. SYNGNATHIFORMES
F. SOLENICHTHYIDAE
Solenostomus sp.1

F. SYNGNATHIDAE
Halicampus grayi
Hippocampus whitei
Solegnathus lettiensis.......165

F. FISTULARIIDAE
Fistularia petimba...........71 (Fistularia commersoni?)

F. CENTRISCIDAE
Centriscus scutatus...........92

O. SCORPAENIFORMES
F. SCORPAENIDAE
Cottapistus cottoides
Dendrochirus brachypterus
Dendrochirus zebra
Erosa erosa...................83
Hypodytes carinatus...........17
Inimicus caledonicus..........41
Liocranium praepositum
Minous trachycephalus.........42
Minous versicolor............123
Paracentropogan longispinus...79
Parascorpaena pictus

Apogon brevicaudatus
Apogon ellioti................23
Apogon c.f. fasciata.........172
Apogon nigripinnis...........105
Apogon poecilopterus..........36
Apogon quadrifasciatus........29
Apogon semilineatus
Apogon septemstriatus.........62
Apogon sp.1
Apogon sp.2 (juvenile)
Apogon sp.3
Apogonichthys sp.1
Archamia fucata
Pristiapogon exostigma
Siphamia fuscolineata
Siphamia sp.1 (juvenile)

F. SILLAGANIDAE
Sillago maculata burrus.......112
Sillago sp.1..................130

F. RACHYCENTRIDAE
Rachycentron canadus

F. ECHENEIDIDAE
Echeneis naucrates

F. CARANGIDAE
Alectis indicus
Alepes apercna
Carangoides hedlandensis
Carangoides humerosus.........148
Carangoides uii
Carangoides c.f. uii
Caranx bucculentus
Decapterus macrosoma
Decapterus russellii
Gnathanodon speciosus

Selar boops
Selaroides leptolepis
Seriolina nigrofasciata......172
Ulua aurochs
Uraspis uraspis

F. FORMIONIDAE
Parastromateus niger..........162

F. LEIOGNATHIDAE
Gazza minuta
Leiognathus bindus............115
Leiognathus decorus
Leiognathus elongatus
Leiognathus equulus...........119
Leiognathus moretoniensis.....126
Leiognathus splendens..........21
Secutor ruconius

F. GERREIDAE
Gerres filamentosus
Gerres sp.1
Gerres sp.2
Pentaprion longimanus.........175

F. LUTJANIDAE
Lutjanus c.f. amabilis (? L. adetii)
Lutjanus carponotatus
Lutjanus erythropteru.s.......174

- Lutjanus malabaricus..........167
- Lutjanus russelli
- Lutjanus sebae...............139
- Lutjanus vitta

F. CAESIONIDAE
- Pterocaesio sp.1
- Pterocaesio sp.2

F. NEMIPTERIDAE
- Nemipterus furcosus...........35
- Nemipterus hexodon............54
- Nemipterus c.f. marginatus}....5
- Nemipterus celebicus }
- Nemipterus zysron
- Nemipterus tolu(peronii)......45
- Nemipterus sp.1
- Pentapodus paradiseus.........70
- Pentapodus sp.1
- Pentapodus sp.2
- Scolopsis monogramma.........126
- Scolopsis taeniopterus........87

F. HAEMULIDAE
- Diagramma pictum..............128
- Pomadasys maculatum............76
- Pomadasys trifasciata.........109

F. LETHRINIDAE
- Gymnocranius bitorquatus
- Lethrinus haemopterus.........176
- Lethrinus nematacanthus........56

F. SPARIDAE
- Argyrops spinifer

F. SCIAENIDAE
- Johnius amblycephalus.........177
- Johnius vogleri...............168

F. MULLIDAE
- Parupeneus cinnabarinus(?)
- Upeneus sulphureus.............77
- Upeneus sundaicus.............114
- Upeneus c.f. tragula...........49
- Upeneus sp.1....................9

F. PEMPHERIDIDAE
- Parapriacanthus ransonneti

F. EPHIPPIDAE
- Drepane punctata
- Platax teira..................133
- Zabidius novemaculeatus

F. CHAETODONTIDAE
- Heniochus acuminatus
- Parachaetodon ocellatus.......127

F. POMACANTHIDAE
- Chaetodontoplus duboulayi

F. POMACENTRIDAE
- Pristotis jerdoni..............34

F. CIRRHITIDAE
- Cirrhitichthys aprinus

F. CEPOLIDAE
- Acanthocepola abbreviata
- Acanthocepola krusensterni

F. SPHYRAENIDAE
- Sphyraena flavicauda

F. POLYNEMIDAE

Polydactylus heptadactylus

F. LABRIDAE

Choerodon cephalotes..........137
Choerodon monostigma..........139
Choerodon vitta...............184
Choerodon sp.1(C. cauteroma?)..46
Choerodon sp.2 (C. sugillatum)

F. OPISTOGNATHIDAE

Opistognathus latitabunda

F. MUGILOIDIDAE

Parapercis diplospilus
Parapercis nebulosa............19

F. URANOSCOPIDAE

Ichthyoscopus fasciatus
Uranoscopus sp.1

F. BLENNIDAE

Meiacanthus geminatus
Xiphasia setifer

F. CALLIONYMIDAE

Callionymus grossi.............27
Callionymus japonicus..........51
Callionymus belcheri...........38
Dactylopus dactylopus..........63
Synchiropus rameus.............28
Repomuscenus limiceps

F. GOBIIDAE

Gobiidae sp.1
Yongeichthys criniger

F. SIGANIDAE

Siganus fuscescens...........125

F. TRICHIURIDAE

Trichiurus lepturus

O. PLEURONECTIFORMES

F. PSETTODIDAE

Psettodes erumei..............99

F. BOTHIDAE

Pseudorhombus argus...........75
Pseudorhombus arsius.........113
Pseudorhombus diplospilus.....59
Pseudorhombus dupliciocellatus47
Pseudorhombus elevatus........50
Pseudorhombus spinosus........32
Pseudorhombus sp.1
Arnoglossus intermedius.......48
Arnoglossus waitei............57
Bothus sp.1
Engyprosopon grandisquama......7
Engyprosopon sp.1
Grammatobothus pennatus.......64
Grammatobothus polyophthalmus.84

F. PLEURONECTIDAE

Samaris cristatus.............81

F. SOLEIDAE

Aesopia cornuta..............151
Dexillichthys muelleri
Pardachirus pavoninus........194
Soleichthys sp.1
Strabozebrias cancellatus....135
Zebrias craticula............110

F. CYNOGLOSSIDAE

Cynoglossus sp.1..............80
Cynoglossus sp.2.............159

O. TETRAODONTIFORMES

F. TETRAODONTIDAE

Amblyrhynchotes spinosissimus
Anchisomus multistriatus....163
Arothron immaculatus
Arothron stellatus
Canthigaster rivulata
Chelonodon patoca
Lagocephalus scleratus........31
Lagocephalus wheeleri
Torquigener brevipinnis
Torquigener parcuspinus
Torquigener tuberculiferus....30
Torquigener whiteleyi..........86

F. TRIACANTHIDAE

Triacanthus biaculeatus
Trixiphichthys weberi........138

F. BALISTIDAE

Abalistes stellaris

F. MONACANTHIDAE

Alutera monoceros
Anacanthus barbatus
Brachaluteres taylori
Chaetoderma penicilligera
Paramonacanthus japonicus......6
Paramonacanthus filicauda
Paramonacanthus sp.1
Pseudomonacanthus peroni

F. DIODONTIDAE

Tragulichthys jaculiferus....124

F. OSTRACIIDAE

Lactoria cornuta.............153
Rhyncostracion nasus..........93
Tetrosomus gibbosus..........136

C. REPTILIA

SC. LEPIDOSAURIA

O. SQUAMATA

F. HYDROPHIIDAE

Acalyptophis peronii
Aipysurus duboisii
Aipysurus laevis
Hydrophis ornatus
Hydrophiidae spp.

P. PORIFERA

several spp.

P. CNIDARIA

Dendronephthia sp.1
Dendronephthia sp.2
Cnidaria spp.

P. SIPUNCULA

severall spp.

P. ANNELIDA

Chloea sp.
Annelid spp.

B. BRYOZOA

several spp.