Analysis of Demersal Fish Assemblages in Selected Philippine Fishing Grounds

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Abstract

This paper presents the results of analyses of demersal fish assemblages in various fishing grounds in the Philippines. Data from exploratory trawl surveys conducted in 1947 - 49 show that the 24 fishing grounds covered by the survey can be arranged along a gradient of substrate type (i.e. relative coral cover and sediment characteristics). These may be used to determine the species commonly caught in these grounds. A trend of increasing catch rates with decreasing water depth and increasing proportion of mud in the substrate was noted. Data from more recent systematic surveys in Samar Sea (1979 - 80), San Pedro Bay (1994 - 95) and Manila Bay (1992 - 93) were analyzed to examine spatio-temporal patterns in fish assemblages. In all 3 areas, the fish community was characterized by a large number of ubiquitous species, with Leiognathids comprising at least 28% of the total catch. In terms of habitat relations, depth was the primary factor in Samar Sea and San Pedro Bay, where transitions in fish assemblage composition were recognizable at certain depth ranges. In Manila Bay, however, species composition appears to be more related to location (inner versus outer portions of the bay).

Analysis of data from five locations (Manila Bay, Tayabas Bay, Sorsogon Bay, Samar Sea and San Pedro Bay) extending from the western to the eastern portions of the country showed similar seasonality, with fish assemblage composition varying slightly during the monsoon season.

Introduction

This paper summarizes analyses of data from selected trawl surveys conducted in the Philippines. The trawl data sources include (1) exploratory surveys (1947 - 49) in 24 fishing grounds around the country; (2) systematic trawl surveys in Samar Sea (1979 - 80), San Pedro Bay (1994 - 95) and Manila Bay (1992 - 93); and (3) quasi-systematic surveys for demersal biomass in Tayabas Bay (1994 - 95) and Sorsogon Bay (1994 - 95). Data were analyzed to: identify assemblages of trawl-caught organisms; examine how these are distributed in space and time within the surveyed areas; and determine if the different areas surveyed showed similar patterns. This information, in turn, can help in the delineation of assemblage boundaries and fishing zones applicable to various fishing grounds in the country.

Historical (1947 - 49) data were analyzed to examine the broad pattern of demersal fish assemblages in the country prior to the expansion of the trawl

fishery in the mid-1970s. This provides insight into possible changes in the composition of demersal resources since that period, and whether such changes are indicative of ecosystem overfishing as reported in other heavily-fished areas.

Materials and Methods

The initial task of the study was to determine the distribution of demersal assemblages in space and time. Because the surveys had different objectives, there are differences in content and resolution of their information. For example, the exploratory surveys did very limited sampling in each fishing ground. The quasi-systematic surveys consisted of monthly sampling, but because fixed trawl stations were not used, this precluded spatial distribution analyses. Only the systematic surveys (with fixed sampling time intervals and trawl stations) allowed analyses across space and time. It was therefore not possible to employ a standard set of analyses for all the surveys. The general approach in data analyses is described in this section, while analytic details are given in separate sections dealing with the different data sets.

Data from the exploratory surveys were used to characterize the 24 fishing grounds with respect to species group composition and apparent habitat characteristics. Data from the systematic and quasi-systematic surveys were then analyzed to examine potential temporal patterns, and to see if similar patterns occur in different areas of the country. Lastly, data from the systematic trawl surveys were examined for extensive spatial analyses and for comparison between seasons.

Temporal Distribution

The objective here was to determine if any of the areas examined showed seasonality in species composition of the catch (e.g. seasonal differences in species caught in an area or relative abundance of the species). To do this, seasons or time slices (i.e. month groupings) within a year were determined by clustering months based on monthly species abundances (i.e. all stations combined). The resulting seasons then served as the time slices within which spatial distributions were further examined.

Spatial Distribution

The spatial distribution of demersal assemblages was examined at 2 levels: at the annual or within year level, and at the seasonal level. An annual characterization of species assemblages and habitats within each survey area was done by combining all monthly species abundance data for each station and then performing the cluster analysis. At the seasonal level, species abundance data for months in the time slice were combined for each station. The stations were then clustered to show the distribution of habitats within the area.

Internal Analysis
Cluster Analysis

All cluster analyses were executed using **T**wo-**W**ay **IN**dicator **SP**ecies **AN**alysis (TWINSPAN) (Hill, 1979), which produced two-way tables in which the row (species) arrangement corresponds to the species clusters (species assemblages) and the column (sample = station or month) arrangement corresponds to the sample clusters (i.e. stations form habitats, months form seasons). Dendrograms were constructed using the information contained in the output files of the software. These provide a visual presentation of the similarity or dissimilarity between the formed clusters. Ordinations were conducted as a way to verify the clusters formed (see below). Where necessary, a frequency of occurrence of 5 - 10% was used as criteria to limit the number of species included in the analysis. Because of apparent reading errors in the software, all data were first transformed (natural logarithms) and pseudospecies cut levels were then determined from a frequency table of the transformed data.

Ordination Analysis

Ordination of samples (stations or months) in "species space" and "sample space" was performed using Detrended Correspondence Analysis (DCA) in the CANOCO program (Ter Braak 1988). Ordination is a method of plotting samples on a coordinate system representing gradients in species abundance (species space) or plotting species along axes representing station (i.e. habitat) or month (i.e. season) preferences (sample space). These plots reveal how distinct (or indistinct) the TWINSPAN-generated clusters were from each other, or how effective the clustering method was.

External Analysis

External analysis refers to the technique of relating community data to habitat information that is

normally not included, and thus external to, the typical samples-by-species data matrix. For the systematic and quasi-systematic trawl surveys, only depth could be extracted (when not recorded) as the habitat factor available for the various stations. It was only with the exploratory surveys that any useful habitat (fishing ground) information other than depth could be extracted, and thus sensibly subjected to external analyses.

Exploratory Trawl Surveys (1947 - 49)

Exploratory trawl fishing in different areas of the country was conducted as part of the Philippine Fishery Program from September 1947 to July 1949 (Warfel and Manacorp 1950). Twenty four areas were surveyed in an effort to explore potential trawling grounds in the country (Fig. 1). Generally, fishing grounds were surveyed only once during the two-year period (Table 1). Two vessels equipped with trawl nets that differed primarily in the length of head and foot ropes were used during the surveys. A total of 228 tows were attempted, 70% of which were successful. The rest were aborted because of underwater obstructions. In 16 of the 24 areas surveyed, at least 3 tows were made.

The semi-processed data are available in (Warfel and Manacorp 1950) as catch per hour of trawling (all tows in an area combined). Although the catch information in several fishing grounds reflects only 1 or 2 tows, all 24 fishing grounds were used in the analysis in an effort to maximize the use of the data. Catches were listed by families in kg·hr^{-1} units. In addition to catch data, information on total (surface) area, average depth, and general bottom characteristics were also reported (Table 1). Substrate information was based on observations recorded in the various fishing grounds during the surveys.
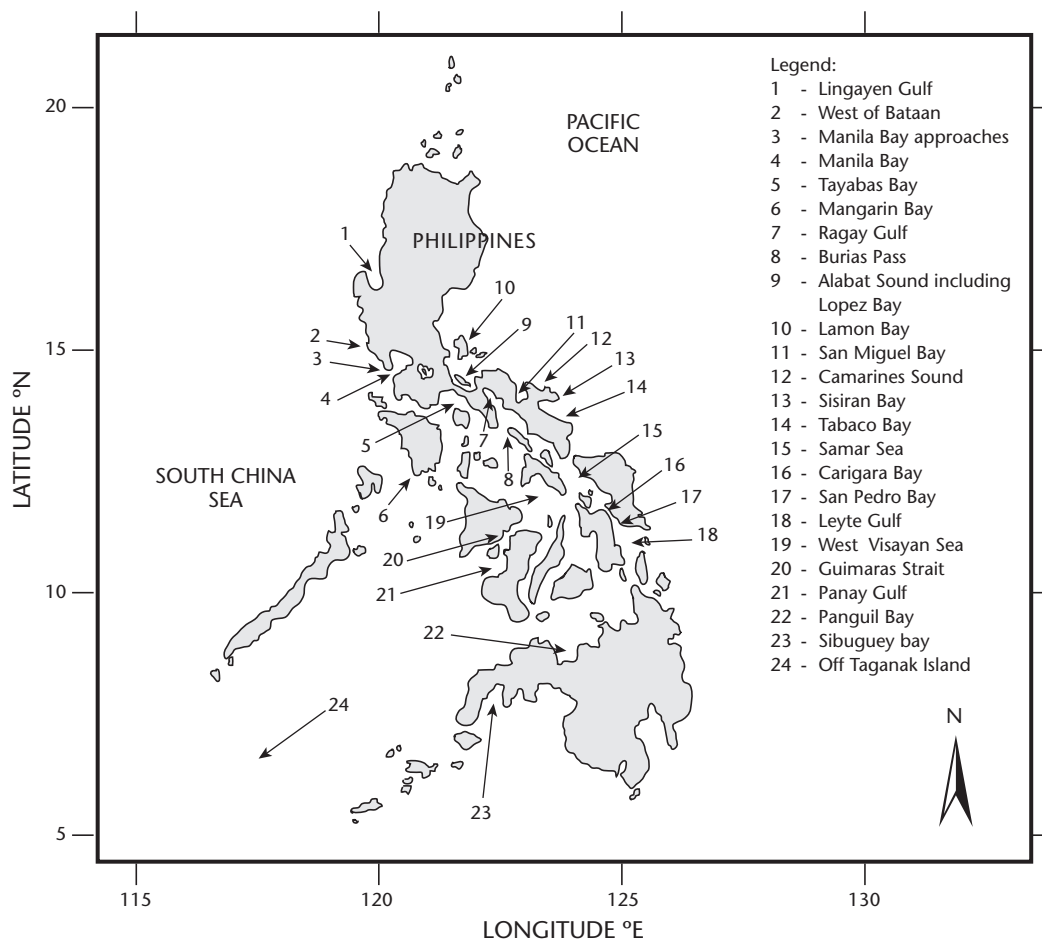

Fig. 1. Locations of the 24 fishing grounds covered during exploratory trawl surveys in 1947 - 49 (Warfel Manacop 1950).

Table 1. Catch and related data for the 24 fishing grounds covered during exploratory trawl surveys from 1947 to 1949 (Warfel and Manacorp 1950).

Area	Fishing ground	Survey dates	Surface area (km²)	Average depth (m)	Mud & sand[a]	Coral cover[b]	CPUE (kg·hr⁻¹)
1.	Lingayen Gulf	Feb - April 1949	1 482	45.8	2	1	67.7
2.	West of Bataan	Oct.1947, Oct. 1948	390	45.8	3	2	11.4
3.	Manila Bay approaches	Oct. to Nov. 1947	520	64.1	3	1	44.1
4.	Manila Bay	Sept. & Nov. 1947	1 352	27.5	2	4	33.6
5.	Tayabas Bay	Nov. 1948	910	64.1	1	5	59.5
6.	Mangarin Bay	Sept. 1948	26	366.0	2	4	40.5
7.	Ragay Gulf	Nov. 1948	1 820	164.7	2	1.5	66.4
8.	Burias Pass	Nov. 1948	520	82.4	1	4	80.0
9.	Lopez Bay	Jul. 1948	481	40.3	1	4	71.8
10.	Lamon Bay	Jul. 1948	2 080	69.5	1	5	136.4
11.	San Miguel Bay	Jul. 1948	520	12.8	1	0	289.1
12.	Camarines Sound	Jul. 1948	4 680	54.9	2	5	59.5
13.	Sisiran Bay	Jul. 1948	52	9.2	1	5	219.1
14.	Tabaco Bay	Jun. 1948	130	73.2	1	4	12.3
15.	Samar Sea	Aug. 1949	780	27.5	2	0	41.8
16.	Carigara Bay	Aug. 1949	520	45.8	2	0	177.3
17.	San Pedro Bay	Aug. 1949	286	14.6	2	4	67.3
18.	Leyte Gulf	Aug. 1949	27	69.5	2	1	27.7
19.	West Visayan Sea	Sept. 1948	650	27.5	1	5	279.5
20.	Guimaras Strait	Aug. and Dec.1948	2 080	18.3	1	4	236.4
21.	Panay Gulf	Jan. and Aug. 1948	520	32.9	1	4	198.5
22.	Panguil Bay	Jul. 1948	377	36.6	1	0	17.7
23.	Sibuguey Bay	Oct. 1949	1 560	32.9	2	4	50.0
24.	Off Taganak Island	Sept. 1949	5 200	36.6	2	5	19.1

Note: [a] Mud & sand scale: 1 = muddy, 2 = mud-sand, 3 = sand-mud, 4 = sand
  [b] Coral cover scale: 1 = patchy heads, 2 = scattered corals, 3 = numerous heads, 4 = large coral heads, 5 = fringing reefs & numerous heads

Fishing grounds were first clustered based on catch abundance of 26 species groups (families) using TWINSPAN. The resulting clusters (species groups and fishing grounds) were then analyzed using Canonical Correspondence Analysis (CCA) in CANOCO and Discriminant Analysis (DA) in STATISTICA, in an attempt to examine habitat relations (external analysis).

Systematic & Quasi-systematic Surveys

These included data from surveys involving fixed stations sampled over regular time intervals (Samar Sea, Manila Bay and San Pedro Bay) and data from surveys involving only randomly-chosen trawling sites sampled monthly to determine stock biomass (Tayabas Bay and Sorsogan Bay). Information pertinent to the systematic trawl survey areas and their respective sampling schemes are shown in Table 2. The location of the surveyed areas are shown in Fig. 2.
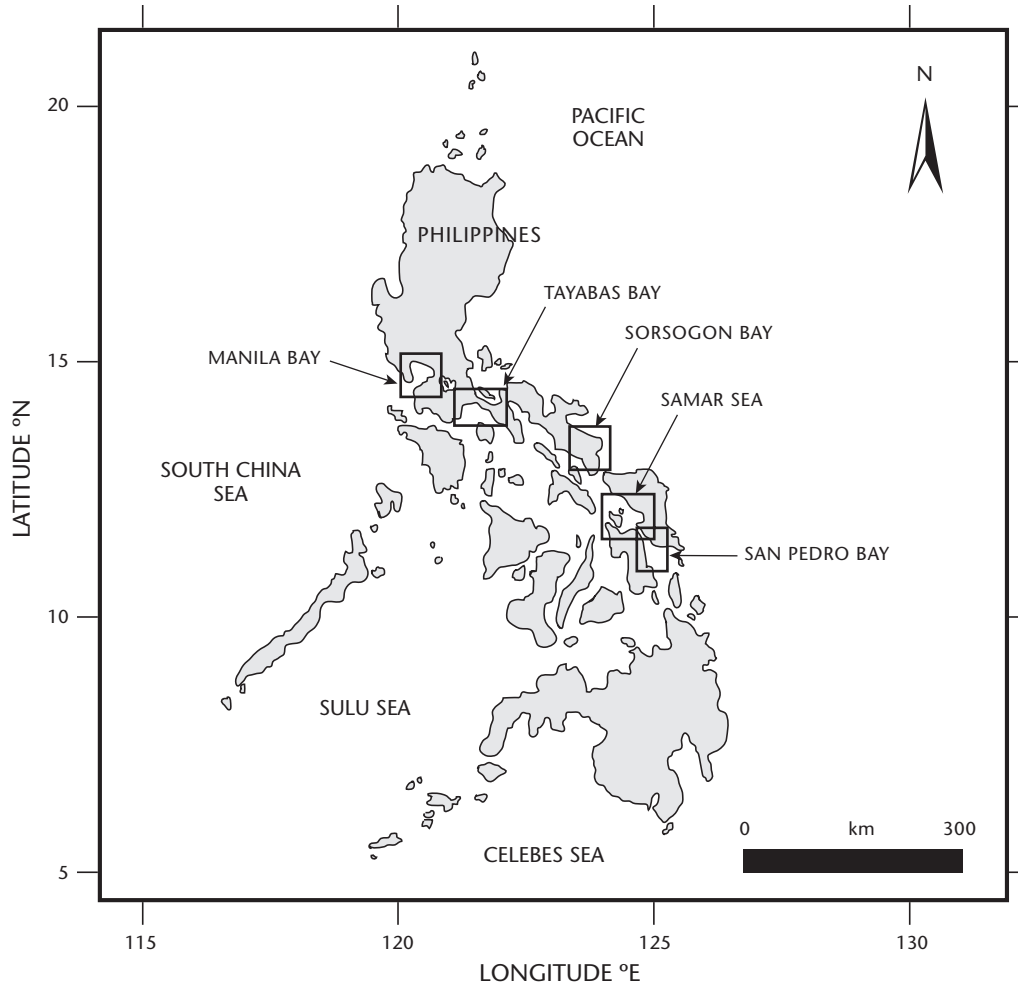

Fig. 2. Locations of areas covered by systematic and quasi-systematic trawl surveys used in the study.

Table 2. Information on systematic trawl survey areas and sampling schemes.

	Samar Sea	San Pedro Bay	Manila Bay	Sorsogon Bay	Tayabas Bay
Surface area (km^2)	3 049	625	1 782	256	1 800[d]

Coordinates
  North Latitude
 	
  East Longitude
	12° 00′ 00″
	
	124° 40′ 00″
		11° 05′ 30″ to
		11° 17′ 30″
		125° 00′ 00″ to
		125° 14′ 00″
			14° 15′ 00″ to
			14° 50′ 00″
			120° 30′ 00″ to
			121° 00′ 00′
				12° 51′ 00″ to
				12° 58.5′ 00″
				123° 51′ 00″ to
				124° 03′ 00″
					13° 15′ 00″ to
					14° 00′ 00″
					121° 18′ 00″ to
					122° 30′ 00″

Sampling period
  No. of Stations
  No. of Months
	Mar 79 - May 80
	28
	11[a]
		Jun 94 - May 95
		13[b]
		12
			Nov 92 - Oct 93
			16
			6
				Apr 94 - Jan 95
				10[c]
				10
					Oct 94 - Jun 95
					8
					9

Fishing vessel	TRV Albacore	F/B Tristan Dos & F/B Roselle	Commercial fishing boat	Mini-trawler	Commercial fishing boat
Type	Steel Hull	With outriggers	With outriggers	With outriggers	With outriggers
Overall length (m)	31.60	15.20 / 17.80	13.50	6.0	–
Breadth (m)	7.00	1.50 / 1.82	1.20		–
Depth (m)	3.20	1.45 / 1.10	1.48	0.5	–
Engine	600 HP	185 HP / 145 HP	Fuzo 4DR5	16HP Gasoline	–
Sampling gear	High opening bottom trawl	Two-seamed net	Otter trawl	Two-seamed net	–
Head-rope (m)	48.80	28.00 / 26.00	15.40	6.0	14.0[e]
Ground-rope (m)	55.0		15.52	6.8	–
Cod-end mesh size (mm)	200	200 / 200	220	117	–
Reference	Armada et al. (1983)	Armada (1996)	MADECOR (Mandala Agricultural Development Corporation) and National Museum (1995)	Cinco and Perez (1996)	Resources Combines Incorporated (1997)

Note: [a] **Survey suspended from Oct 79 to Jan 80**
   [b] **3 out of original 16 stations with incomplete data**
   [c] **Not all stations were sampled regularly. In some months, hauls at some unspecified stations were unsuccessful.**
   [d] **Surface area of the bay estimated from nautical chart and includes a large portion (~ 30%) with depths > 200m**
   [e] **Head-rope estimated from raising factors used in deriving biomass estimates from CPUE (kg·h^{-1}) estimates.**

For the systematic trawl surveys, both spatial and temporal distributions of species and samples were analyzed. For samples, station clusters reflect (spatial) habitats, while month clusters (temporal-annual) reflect seasons of the species clusters (species assemblages) formed. To examine seasonality in the distribution of species and habitats (temporal-seasonal), spatial analyses were also conducted within each time slice formed in the temporal annual analyses.

In the case of quasi-systematic surveys, only temporal analyses could be done, since sampling stations were randomly chosen in each sampling period. This allowed a comparison of seasons (i.e. formed by month clusters based on temporal species occurrences and abundances) among different areas of the country.

Results
Exploratory Trawl Survey (1947 - 49)

The two-way table formed by the resulting clusters of families and fishing grounds is shown in Fig. 3. The families formed 2 broad groups. One is uncommon or even absent in (the first 2 groups of) fishing grounds, where the substrate is a mixture of mud and sand, with low to moderate coral cover. The other broad group is relatively common in these grounds, and includes typical soft-bottom demersal families, such as Sciaenidae, Gerreidae,

Synodontidae, Psettodidae and Nemipteridae. Species clusters 4 and 5 were most frequently recorded in fishing grounds with sandy substrate and coral cover ranging from low to high. These include common reef groups such as Sphyraenidae, Pomadasyidae, Serranidae and Lutjanidae.

Figure 4 shows the clustering of fishing grounds superimposed on a map of the country. Figs. 5a and b show the CCA plots of the fishing ground and species group clusters formed by the cluster analyses, while Fig. 5c shows the plot of environmental factors in the same ordination space. Figure 6 shows the 24 areas in environmental space, based on canonical roots resulting from discriminant analysis. The results of the latter, while not allowing direct correlations with habitat factors, are nevertheless consistent with those suggested by the clusters and by the CCA. It thus appears that the 24 areas can be arranged in gradients reflecting their substrate make-up (i.e. relative coral cover and sediment characteristics), which in turn somewhat determines the kind of species commonly caught in them. These characteristics however do not discount the importance of other factors such as water depth. Catch rate ($kg \cdot hr^{-1}$) was negatively correlated with both average water depth (-0.48, $p < 0.05$) and mud/sand substrate (-0.51, $p < 0.05$), and reflects an underlying trend of increasing catch rates in areas with shallower and more muddy bottoms. This is also consistent with the distribution of the more abundant families in the catches (e.g. Leiognathidae, Mullidae).
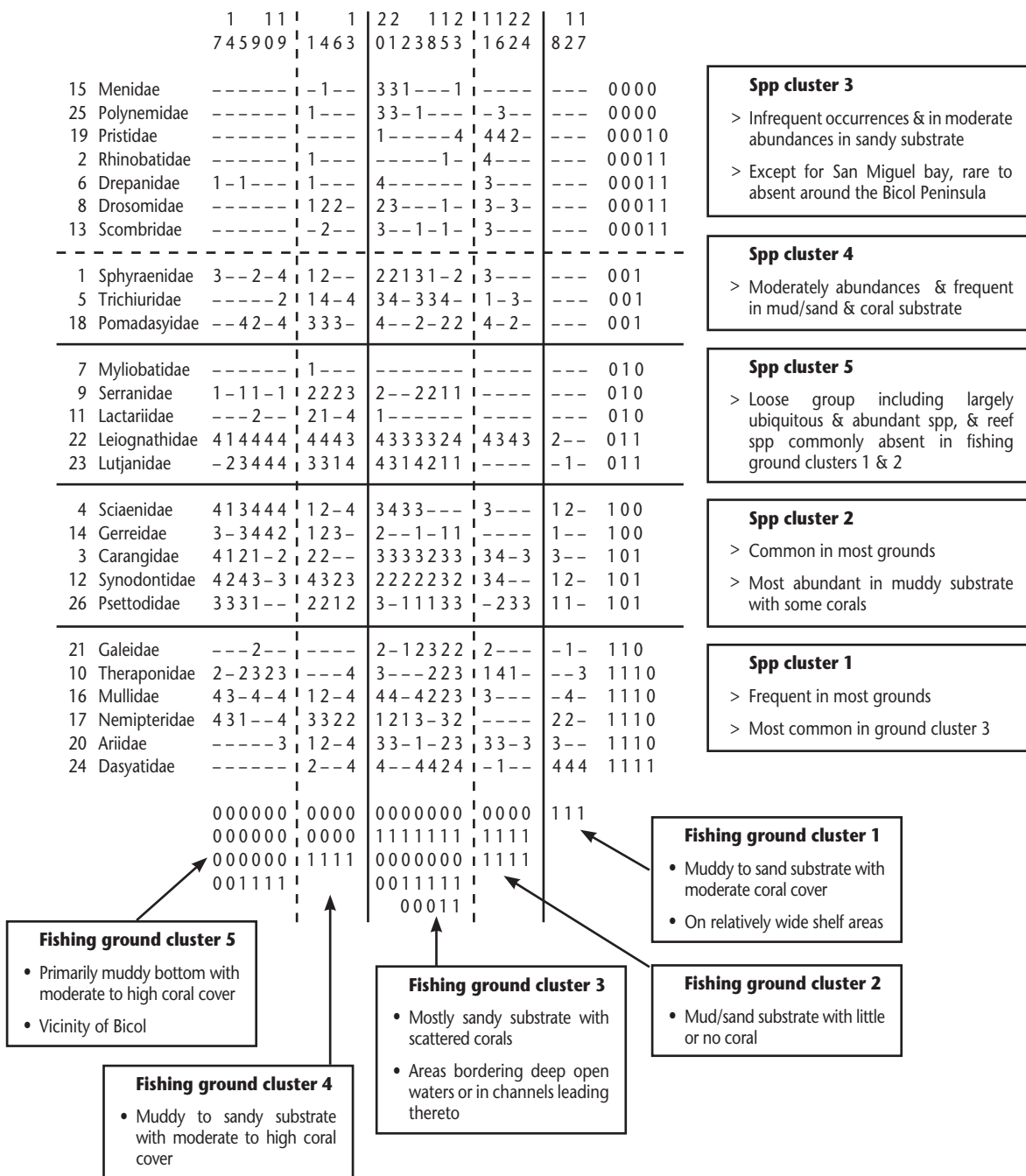
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                    1   11 │    1 │22   112 │1122 │11
                    745909 │1463 │0123853 │1624 │827

15  Menidae        ------ │-1-- │331---1 │---- │---   0000
25  Polynemidae    ------ │1--- │33-1--- │-3-- │---   0000
19  Pristidae      ------ │---- │1-----4 │442- │---   00010
 2  Rhinobatidae   ------ │1--- │-----1- │4--- │---   00011
 6  Drepanidae     1-1--- │1--- │4------ │3--- │---   00011
 8  Drosomidae     ------ │122- │23---1- │3-3- │---   00011
13  Scombridae     ------ │-2-- │3--1-1- │3--- │---   00011
- - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 1  Sphyraenidae   3--2-4 │12-- │22131-2 │3--- │---   001
 5  Trichiuridae   -----2 │14-4 │34-334- │1-3- │---   001
18  Pomadasyidae   --42-4 │333- │4--2-22 │4-2- │---   001

 7  Myliobatidae   ------ │1--- │------- │---- │---   010
 9  Serranidae     1-11-1 │2223 │2--2211 │---- │---   010
11  Lactariidae    ---2-- │21-4 │1------ │---- │---   010
22  Leiognathidae  414444 │4443 │4333324 │4343 │2--   011
23  Lutjanidae     -23444 │3314 │4314211 │---- │-1-   011

 4  Sciaenidae     413444 │12-4 │3433--- │3--- │12-   100
14  Gerreidae      3-3442 │123- │2--1-11 │---- │1--   100
 3  Carangidae     4121-2 │22-- │3333233 │34-3 │3--   101
12  Synodontidae   4243-3 │4323 │2222232 │34-- │12-   101
26  Psettodidae    3331-- │2212 │3-11133 │-233 │11-   101

21  Galeidae       ---2-- │---- │2-12322 │2--- │-1-   110
10  Theraponidae   2-2323 │---4 │3---223 │141- │--3   1110
16  Mullidae       43-4-4 │12-4 │44-4223 │3--- │-4-   1110
17  Nemipteridae   431--4 │3322 │1213-32 │---- │22-   1110
20  Ariidae        -----3 │12-4 │33-1-23 │33-3 │3--   1110
24  Dasyatidae     ------ │2--4 │4--4424 │-1-- │444   1111

                   000000 │0000 │0000000 │0000 │111
                   000000 │0000 │1111111 │1111
                   000000 │1111 │0000000 │1111
                   001111 │     │0011111
                                 │00011
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Spp cluster 3

> Infrequent occurrences & in moderate abundances in sandy substrate

> Except for San Miguel bay, rare to absent around the Bicol Peninsula

Spp cluster 4

> Moderately abundances & frequent in mud/sand & coral substrate

Spp cluster 5

> Loose group including largely ubiquitous & abundant spp, & reef spp commonly absent in fishing ground clusters 1 & 2

Spp cluster 2

> Common in most grounds
> Most abundant in muddy substrate with some corals

Spp cluster 1

> Frequent in most grounds
> Most common in ground cluster 3

Fishing ground cluster 1
- Muddy to sand substrate with moderate coral cover
- On relatively wide shelf areas

Fishing ground cluster 2
- Mud/sand substrate with little or no coral

Fishing ground cluster 3
- Mostly sandy substrate with scattered corals
- Areas bordering deep open waters or in channels leading thereto

Fishing ground cluster 4
- Muddy to sandy substrate with moderate to high coral cover

Fishing ground cluster 5
- Primarily muddy bottom with moderate to high coral cover
- Vicinity of Bicol

Fig. 3. Two-way table of TWINSPAN results for data from 24 fishing grounds (26 species groups) around the Philippines.
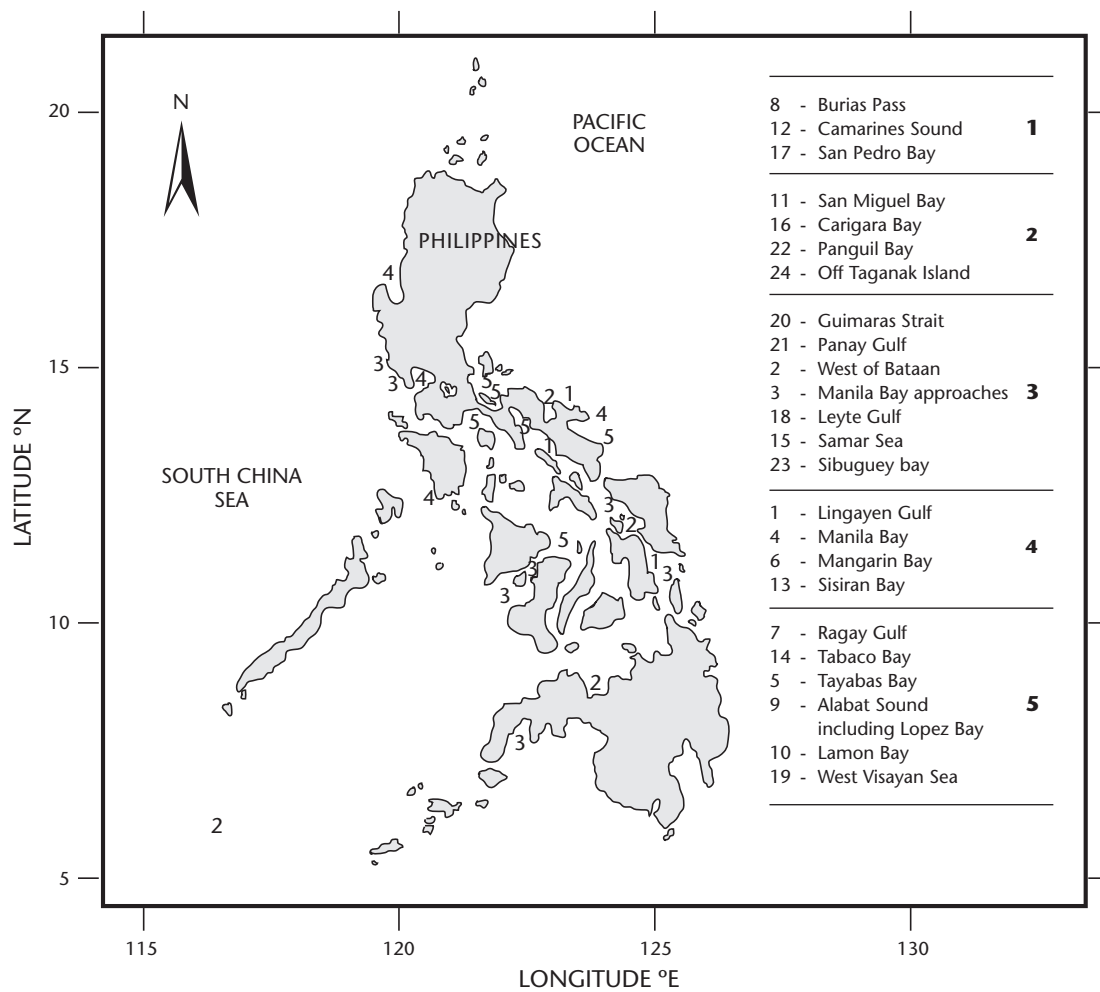
Fig. 4. Map showing the location of fishing ground clusters formed in the analyses of data from Warfel and Manacop (1950).
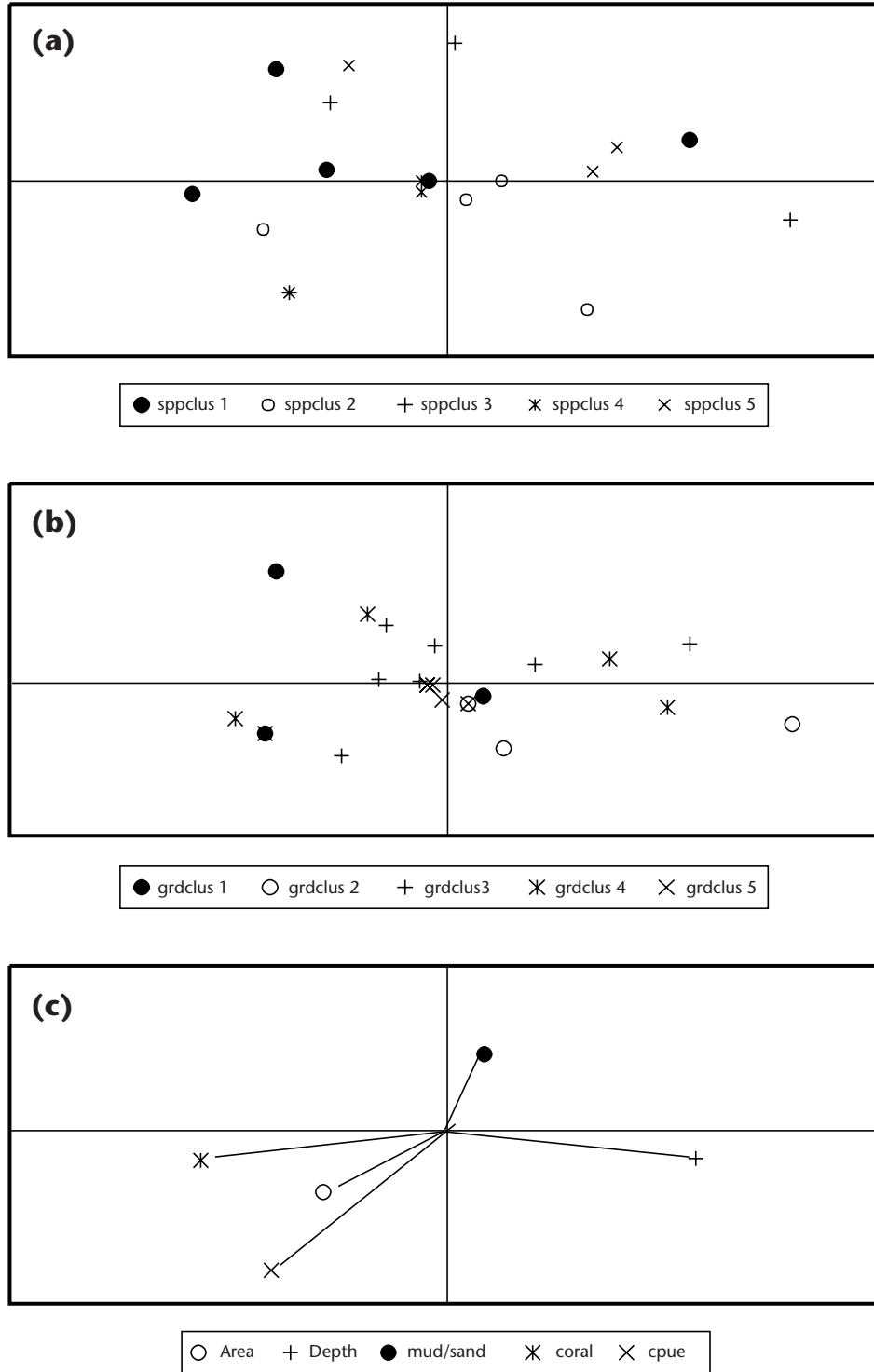
Fig. 5. (a) CCA plot of fishing ground clusters, (b) species group clusters, and (c) environmental factors for the 24 areas sampled during the exploratory surveys in 1947 - 49. The x and y axes are CCA Axes 1 and 2, respectively. In (a) and (b), the various symbols refer to the different species group or fishing ground clusters formed by the cluster analysis.
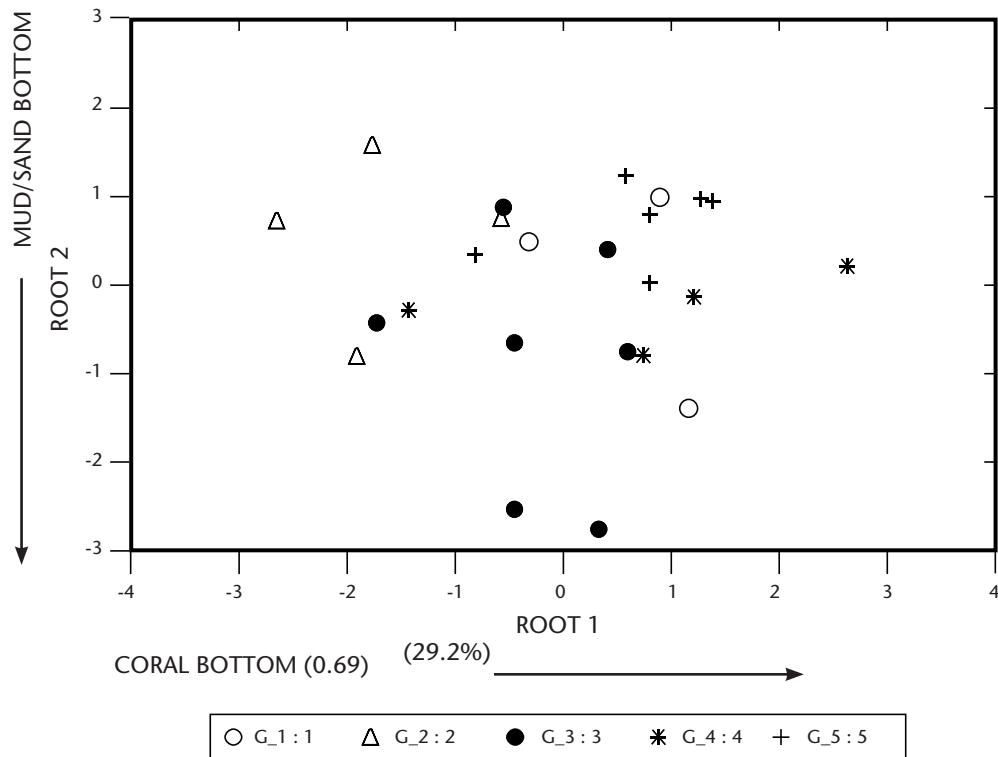
Fig. 6. Plot of 24 fishing grounds (cluster membership shown in legend at lower right of figure) in environmental space (i.e. canonical roots derived by discriminant analysis). Percentages refer to portion of total variation in the data accounted for by each root. Roots are defined by variables showing the highest correlations (in parentheses) with them.

Systematic and Quasi-systematic Trawl Surveys

Generally, the demersal resources in Manila Bay, San Pedro Bay and Samar Sea are characterized by a large number of ubiquitous species that occur in varying abundances across the different habitats in the areas surveyed. In all three areas leiognathids comprised at least 28% of the total trawl catches, and together with squid (*Loligo* spp) comprised up to 59% of the total catch (Tables 3 - 5).

In terms of habitat relations, depth appears to be the primary factor in San Pedro Bay and Samar Sea. In San Pedro Bay, catch species composition shows a transition at depths of 15 - 20 m (Figs. 7 & 8).

This depth range transition is also consistent throughout the year. Temporal analysis of the data showed the following grouping of months: June - July, August - November, and December - May; roughly corresponding to the monsoon and inter-monsoon seasons. The spatial distributions of station clusters during the SW monsoon and inter-monsoon seasons show little variation from the overall annual pattern (Fig. 8), particularly the transition in species assemblage distribution at the 15 - 20 m depth range.

Similarly, demersal assemblage composition in Samar Sea shows a transition at the 30 - 40 m depth range, and again at the depths of 50 - 60 m, with further differences in composition between inner

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(southern) and outer (northern) stations in deeper areas (Figs. 9 & 10). As in San Pedro Bay, the results of the temporal analysis again closely paralleled the monsoon and inter-monsoon seasons; April - June, July - October, and February - June. Spatial analysis within each season showed close similarities with the overall annual pattern, with the depth range transition in species assemblages remaining constant all year round but also with some intensification of the inner-outer differences in station clustering towards and during the southwest monsoon season.

Manila Bay shows a different pattern, since changes in species composition appear to be more related to location (i.e. inner or outer portions) than to depth (Figs. 11 & 12). In both inner and outer portions there are also qualitative differences in species composition between the western and eastern halves of the bay (Fig. 12). Again, similar to the previous two areas, this general annual pattern is shown throughout the year, although some seasonal differences in the delimitation of inner and outer portions of the bay are evident. Whether such variations are the result of factors like local hydrography, bay topography, watershed characteristics or fishing effort distribution is not known, but it would be interesting to investigate further. The temporal pattern in Manila Bay shows a clear correspondence with the Northeast (November - March) and Southwest (May - September) monsoon seasons.

In all of the above three areas, seasonality or within-year differences in species distribution and composition reflect the monsoon and inter-monsoon systems. This is also shown in the results of the temporal analysis of data from Sorsogon Bay and Tayabas Bay (Figs. 13 & 14). In Sorsogon Bay, the grouping of months are April - July, August - November, and December - February. In Tayabas Bay, the transition months June, October and December grouped together, while the regular monsoons were formed by the remaining months. The question of possible differences in the effects of the monsoon systems on the distribution of demersal resources in different portions of the country (e.g. South China Sea coast, interisland waters and Pacific coast) still remains. This may be addressed when sufficient data for the different regions become available.

Table 3. Most abundant trawl-caught species in Samar Sea, 1979 - 80.

Species	% of total catch
Leiognathus bindus	25.30
Loligo sp.	5.93
Pentaprion longimanus	5.93
Saurida undosquamis	4.70
Saurida tumbil	3.60
Upeneus sulphureus	3.10
Nemipterus nematophorus	3.10
Leiognathus splendens	2.84
Rastrelliger brachysoma	2.74
Decapterus macrosoma	2.63
Apogon spp.	2.30
Sepia sp.	2.27
Leiognathus equulus	2.22
Trichiurus haumela (T. lepturus)*	2.22
Rastrelliger kanagurta	2.01
Sphoeroides lunaris (Lagocephalus lunaris)*	1.95
Priacanthus macracanthus	1.76
Priacanthus tayenus	1.73
Fistularia spp.	1.70
Stolephorus indicus	1.31

* Valid name in Fish Base

Table 4. Most abundant trawl-caught species in San Pedro Bay, 1994 - 95.

Species	% of total catch
Leiognathus splendens	26.18
Leiognathus bindus	17.43
Gazza minuta	6.54
Secutor ruconius	4.51
Leiognathus equulus	3.64
Dussumieria acuta	3.01
Loligo sp.	2.39
*Gerres abbreviatus (G. erythrourus)**	2.21
Nemipterus hexodon	2.18
Saurida tumbil	2.02
Leiognathus leuciscus	1.93
*Trichiurius haumela (T. lepturus)**	1.86
Apogonidae	1.58
Secutor insidiator	1.49
Selariodes leptolepis	1.30
*Stolephorus commersoni (S. commersonii)**	1.21
Holothuridae	0.99
Pentaprion longimanus	0.97
Sardinella gibbosa	0.78
Scolopsis taeniopterus	0.75

* Valid name in Fish Base

Table 5. Most abundant trawl-caught fishes in Manila Bay, 1992 - 93.

| Species	% of total catch
Loligo sp.	22.70
Secutor insidiator	12.61
Leiognathus bindus	10.31
Gazza minuta	5.38
*Trichiurus haumela (T. lepturus)**	3.25
Thryssa setirostris	2.49
*Stolephorus bataviensis (S. waitei)**	2.37
Gerres filamentosus	2.29
Atule mate	2.24
Stolephorus indicus	2.06
Valamugil seheli	2.04
Apogon sp.	1.98
Pelates quadrilineatus	1.89
Upeneus tragula	1.65
Stolephorus commersonii	1.61
Stolephorus sp.	1.54
Sardinella fimbriata	1.51
*Caranx malabaricus (Carangoides malabaricus)**	1.41
*Pennahia macrophthalmus (P. anea)**	1.32
Arothron stellatus	1.22

* Valid name in Fish Base
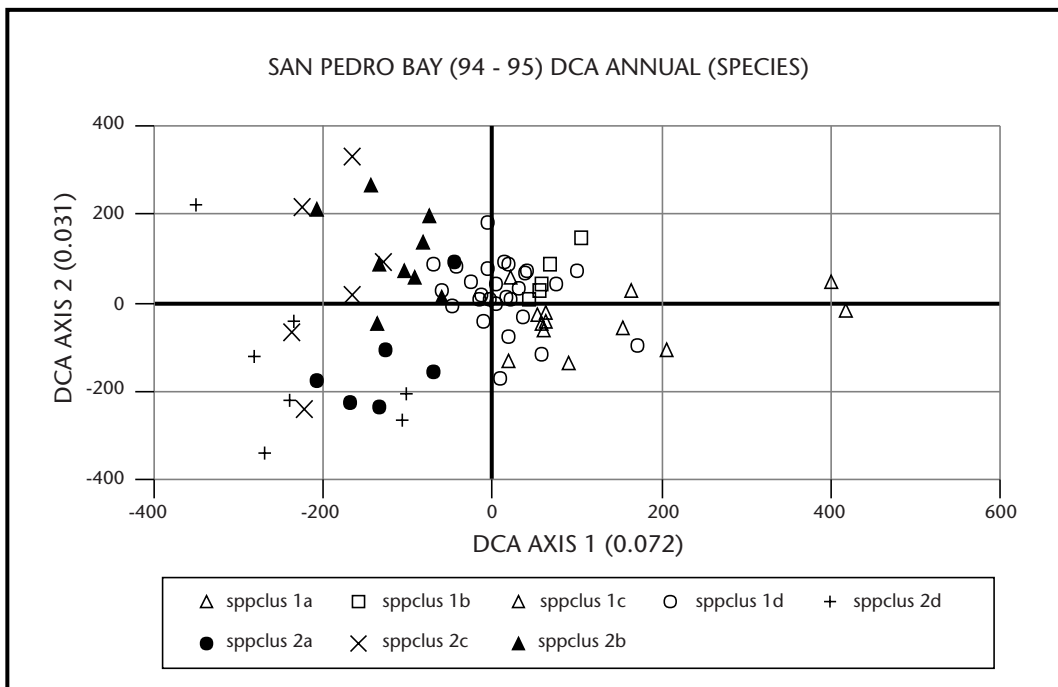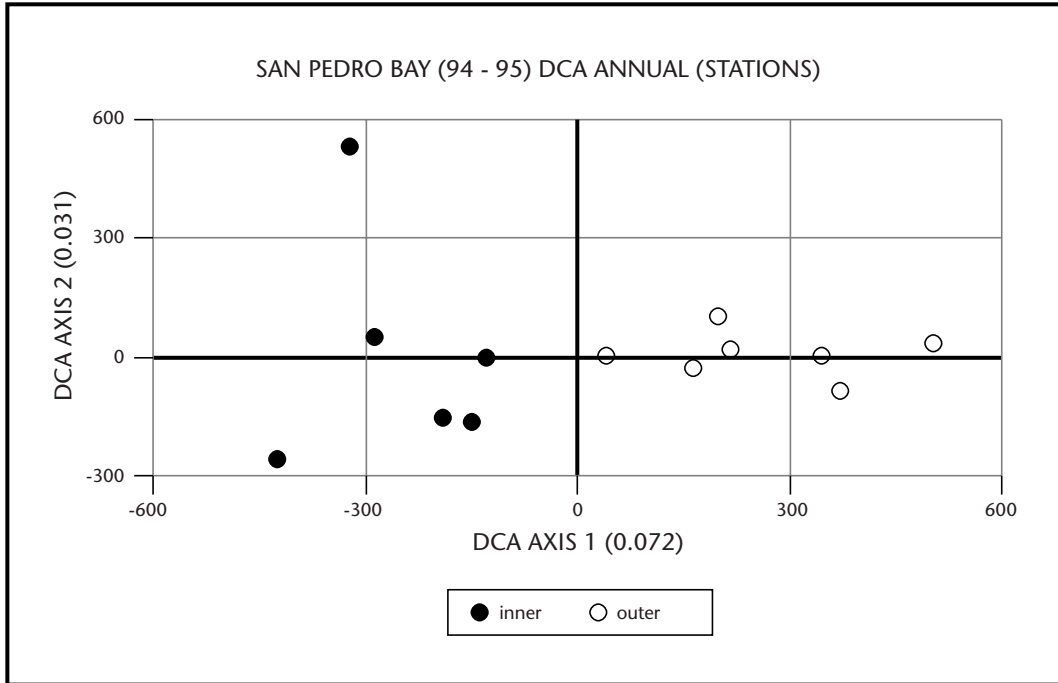
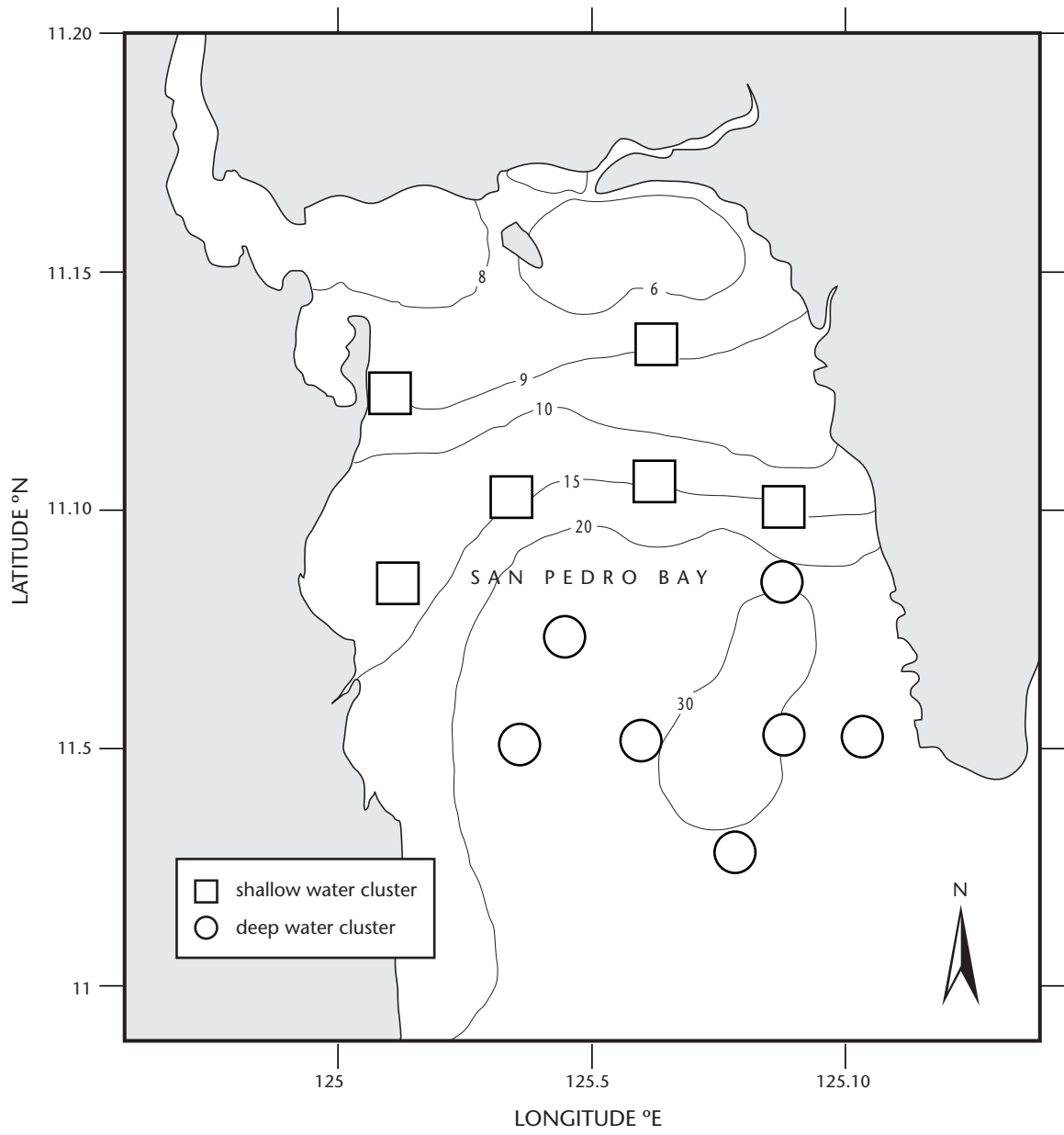Fig. 7. Ordination of stations (above) and species (below) in the spatial analysis of San Pedro Bay data.

Fig. 8. Map of station cluster locations in San Pedro Bay based on the annual spatial analysis. Isobaths are in meters.

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                    ┌────────────┐                      ┌──────────────┐
                    │ Inner Deep │                      │Outer Shallow │
                    └─────┬──────┘                      └──────┬───────┘
  ┌────────────┐          │                                    │        ┌──────────────┐
  │ Outer Deep ├──►       ▼                      ▼             │   ◄────┤ Inner Shallow│
  └────────────┘                                                        └──────────────┘

                   11    1      112 | 122222 | 12   2 | 12   11
                   1 3890567490     | 281567 | 52344  | 283176

  4  Brac  spp     33332122322      | 322112 | –1–1–  | ––––––  000
 47  Trig          54111111344      | 442234 | –1––1  | ––––––  000
 22  Nemi  nem     55544445444      | 544244 | 23343  | –22––1  001
 25  Pria  mac     54443355444      | 442223 | 32–41  | –1–––2  001
 28  Pter  spp     2223–212232      | 332333 | –1322  | 1–––2–  001
 50  Urab  spp     33212222112      | 431223 | 3–111  | 11––––  001

  2  Alut  mon     22–1221–122      | 333334 | 32113  | –1––13  010
  8  Deca  mac     53343222223      | 242444 | 21–32  | 133–25  01100
 11  Fist  spp     44443444444      | 453344 | 33333  | 332–22  01100
 10  Epin  sex     2223–333333      | 342334 | 31332  | –22113  01101
 23  Pent  lon     54554433444      | 554555 | 45445  | 333122  01101
 34  Saur  und     45554455555      | 444334 | 44443  | 442333  01101
 51  Uras  hel     2133–333222      | 332222 | 3233–  | 211–12  01101
  9  Elat  spp     ––1–3323122      | 13221  | 33232  | 111113  011100
 26  Pria  tay     44333444444      | 344344 | 44444  | 224233  011100
 35  Scol  tae     2–332224212      | –22433 | 33334  | 123122  011100
 43  Sphy  lan     31–43311–12      | 231122 | 12224  | 2121––  011100
  3  Apog  spp     44443444444      | 444444 | 44443  | 443344  011101
  7  Cham  spp     3232–222222      | 222122 | 23232  | 221221  011101
 13  Leio  bin     65555555455      | 555655 | 45555  | 544343  011101
 17  Loli  spp     54443444444      | 454544 | 54545  | 554555  011101
 18  Natn  sp      21121111122      | 211122 | 11131  | 111222  011101
 19  Nemi  bat     –133–222212      | –33333 | 23222  | 3231–2  011101
 21  Nemi  jap     43333333433      | 333223 | 43432  | 433444  011101
 24  Plat  spp     33121222212      | 4–1121 | 12222  | 231332  011101
 27  Pset  eru     322–22–1222      | 31332  | ––222  | 33212–  011101
 29  Rast  bra     24334353344      | 344444 | 45444  | 335334  011101
 30  Rast  kan     33423432545      | 2–1343 | 42453  | 443343  011101
 32  Sard  sam     2231–232222      | 122333 | 23212  | 233343  011101
 33  Saur  tum     45544445444      | 444444 | 44444  | 444444  011101
 39  Sepi  spp     44442444444      | 444434 | 44453  | 444344  011101
 40  Seri  nig     4234–323222      | 332312 | 13332  | 222311  011101
 41  Spho  lun     44442444444      | 443333 | 43443  | 343444  011101
 45  Stol  ind     32233434334      | 423344 | 44442  | 433344  011101
 46  Tric  hau     34332333332      | 415225 | 54353  | 432443  011101
 48  Upen  sul     444–2444444      | 544454 | 34444  | 444443  011101
  5  Cara  mal     2122–312–21      | 332332 | 23323  | 121232  01111
 31  Rept  3       3211–1–2333      | 31323  | 33113  | 132133  0111

 36  Scom  com     –––2–313132      | –13442 | 33333  | 343433  1000
 37  Sela  mat     –4–––432222      | –22432 | 33344  | 333132  1000
 38  Sela  lep     –2–3–321333      | 133433 | 34434  | 444433  1000
 49  Upen  sun     11–2–322232      | 343323 | 33233  | 233333  1000
 20  Nemi  hex     11332122111      | 23–333 | 33323  | 333333  1001
 42  Sphy  jel     32–1––––312      | 333–44 | 2–222  | 323333  1001
 44  Sphy  obt     21––211221–      | 412223 | 23–34  | 223322  1001
  1  Alep  dje     –––––23–112      | 1–3332 | 32452  | 234432  101
 15  Leio  leu     431––2112––      | 3–1332 | 43434  | 432423  101

  6  Cara  arm     11–––222211      | –12221 | 22332  | 333332  11
 12  Gerr  kap     –1–––1111–1      | –1–––– | 32342  | 233434  11
 14  Leio  equ     –––––––11–2      | 2222–2 | 44454  | 444544  11
 16  Leio  spl     –––––––11––      | –1–––– | 43553  | 354545  11

                   00000000000      | 000000 | 11111  | 111111
                   00000000000      | 111111 | 00000  | 111111
                   00111111111      | 001111 | 00111  | 000001
                     000111111      |        |        | 00011
                        000111      |        |        |
```

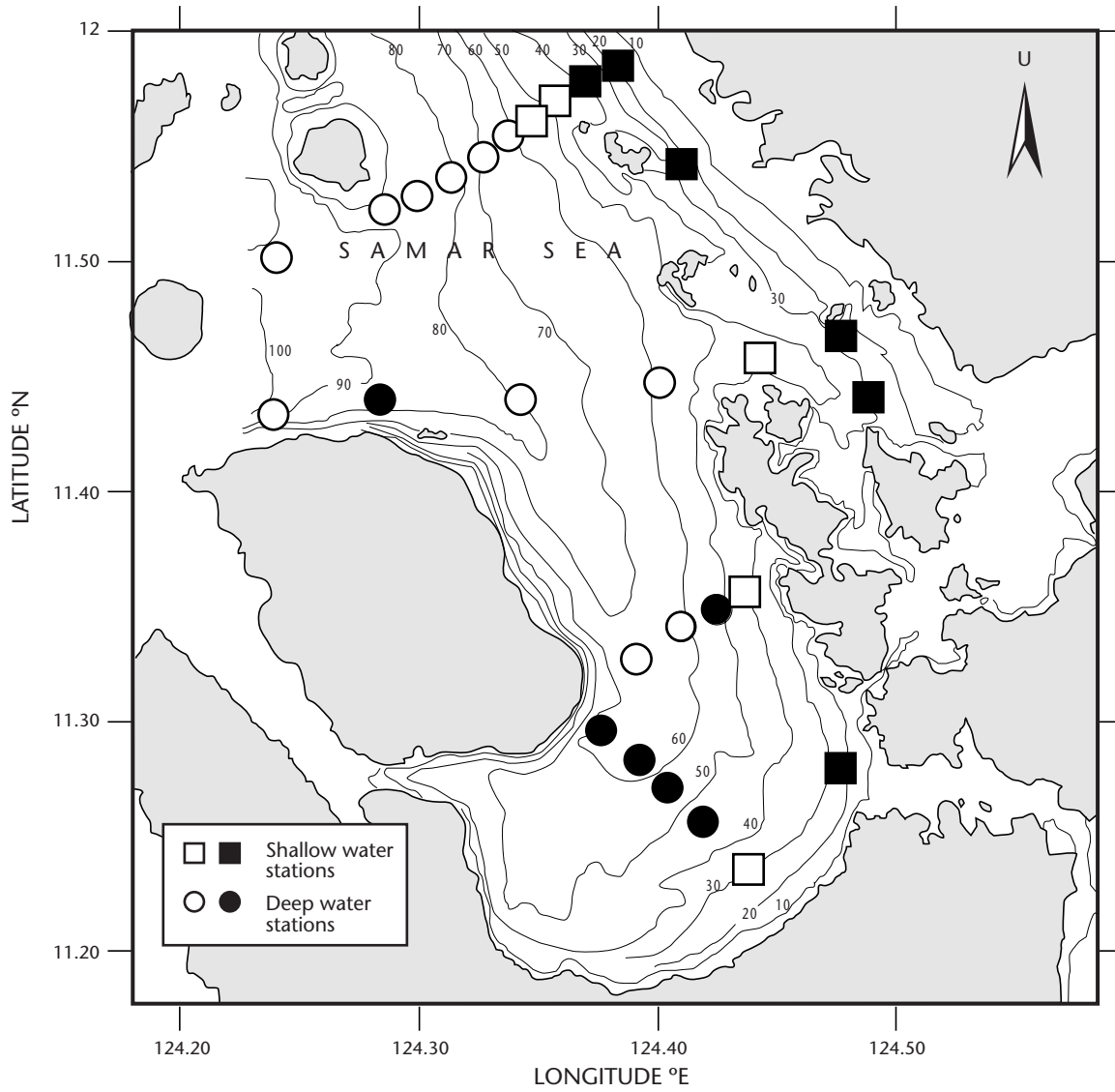**Fig. 9. Two-way table output for annual spatial analysis of Samar Sea data.**

Fig. 10. Map of station cluster locations in Samar Sea for the entire study period, March 1979 - May 1980 (annual spatial analysis). Isobaths are in meters.

		Inner		Outer		
		1 1 1 / 0 1 2	5 7 8 9 6 1	2 3 4	1 1 1 1 / 3 4 5 6	
3	Mugicep	2 4 4	– – – – – 2	– – –	– – – 1	0 0 0
14	Scomcom	– – 1	– 1 2 2 3 2	– – –	1 – – –	0 0 0
16	Eleutet	3 3 4	– 3 3 2 1 1	– – –	– – – 1	0 0 0
32	Stolbat	5 5 6	2 6 5 5 3 7	– – –	– – – –	0 0 0
27	Sciaenid	6 1 4	2 – 6 6 2 –	– – –	1 – 1 2	0 0 1 0
28	Stoltri	4 4 4	6 6 6 5 6 –	– – 6	3 – – –	0 0 1 0
37	Stolcom	6 7 7	5 4 4 6 4 5	3 5 –	2 – – –	0 0 1 1 0
39	Pennmac	4 5 6	3 4 3 4 4 2	– 1 –	2 – 4 4	0 0 1 1 0
43	Sillsih	4 3 3	4 3 1 3 4 3	1 3 1	– – – 2	0 0 1 1 0
44	Thryset	6 5 4	4 6 4 4 5 4	– 4 6	1 – 1 –	0 0 1 1 0
23	Nemanas	4 4 5	– 4 3 2 – –	– – –	– – 3 2	0 0 1 1 1
25	Valaseh	4 6 6	2 2 – 2 – 2	2 2 2	– – – –	0 0 1 1 1
17	Stolepho	7 5 6	– – – 5 – 7	6 4 –	– – – –	0 1 0
18	Therjar	1 2 2	– – 1 1 – 2	– 2 1	– – – 1	0 1 0
22	Lagoine	3 3 3	2 – – 2 1 3	– 2 –	– 4 – 1	0 1 0
35	Leiospl	4 4 4	1 – – – 3 3	3 4 4	– – – 2	0 1 0
34	Alepmel	2 2 2	– 4 1 2 3 2	3 2 2	– – – 2	0 1 1 0 0
46	Sardfim	4 4 7	2 4 4 3 2 4	3 4 3	– – – 4	0 1 1 0 0
48	Atulmat	4 4 3	3 5 3 4 5 1	– 2 3	2 1 4 4	0 1 1 0 0
54	Gerrfil	6 5 5	4 5 4 4 4 4	2 4 3	– – 4 4	0 1 1 0 0
36	Pelaqua	2 3 1	2 2 2 2 4 1	– 2 1	– 1 3 6	0 1 1 0 1 0
50	Caramal	3 3 4	4 4 2 3 4 3	2 4 4	1 3 4 –	0 1 1 0 1 0
51	Penaeus	4 4 4	3 4 3 3 4 4	1 3 3	3 – 4 3	0 1 1 0 1 0
2	Megacyp	– 1 –	– 1 – 2 – –	– 1 –	– – 2 –	0 1 1 0 1 1
42	Nemijap	2 – –	2 3 2 3 4 3	– 1 3	2 – 3 4	0 1 1 0 1 1
45	Upensul	1 2 2	1 3 – 3 5 3	3 3 2	– – 4 3	0 1 1 0 1 1
55	Trichau	4 3 2	4 4 4 6 4 5	2 5 5	4 2 5 5	0 1 1 0 1 1
56	Secinsi	6 4 4	4 7 6 5 6 7	7 7 7	1 4 6 4	0 1 1 0 1 1
57	Loligos	6 5 5	6 6 6 7 6 6	5 6 6	5 4 6 6	0 1 1 0 1 1
9	Rastkan	2 – –	3 3 1 – – –	– 2 1	– – 1 –	0 1 1 1
11	Gobiidae	– 1 2	2 2 – – 3 –	– – 1	1 – 2 –	0 1 1 1
12	Platycep	– 1 1	– 3 1 1 1 –	– – –	– 2 – 2	0 1 1 1
6	Valamugi	– 1 2	– – – – 2 2	– 2 2	– – – –	1 0 0 0
7	Caraarm	– – –	– – 2 2 2 2	– 4 2	– – – –	1 0 0 0
26	Scatarg	– – –	2 – 1 – 1 2	1 3 2	– – – 1	1 0 0 1 0
38	Leioequ	1 1 –	2 2 1 – 2 4	3 4 4	– – – 2	1 0 0 1 0
10	Sphyfor	– 1 –	– – – 1 2 4	1 2 2	– 4 – –	1 0 0 1 1
20	Caradin	– – –	– 3 1 2 1 1	– 3 –	– 1 3 –	1 0 0 1 1
49	Gazzmin	2 4 4	4 4 2 4 6 4	4 6 4	2 4 3 4	1 0 0 1 1
53	Apogons	2 3 3	5 4 3 3 5 6	2 3 6	5 6 5 5	1 0 0 1 1
19	Sphyjel	– – 2	1 1 1 2 – 2	– – –	– 2 3 4	1 0 1 0
21	Alecind	2 – –	2 – 2 1 1 –	– 2 –	2 – 3 2	1 0 1 0
31	Squilla	– – 2	2 – 1 – 5 3	– 2 2	2 3 4 3	1 0 1 0
8	Pomamac	– 2 –	– – – – 2 1	– 1 2	– – 1 2	1 0 1 1
29	Sphybar	3 2 2	– 2 2 1 – –	2 2 –	– 1 3 2	1 0 1 1
47	Crabs	1 4 2	1 1 1 1 1 1	1 1 1	3 3 3 2	1 0 1 1
33	Stolind	– – –	– 6 – – – 6	2 5 4	– – 4 6	1 1 0 0 0
40	Selalep	– – –	– 4 – 1 4 –	4 5 3	2 – 4 2	1 1 0 0 0
41	Leioleu	2 1 –	2 3 2 3 4 2	6 5 3	– 3 3 4	1 1 0 0 0
1	Aleccil	1 1 –	1 – – – – –	– 3 –	– – 2 –	1 1 0 0 1
24	Tetraodo	1 1 –	– 2 1 1 – 1	2 2 3	– 2 – 2	1 1 0 0 1
30	Saurtum	– 1 –	1 1 – – – 2	3 3 2	– – 3 –	1 1 0 0 1
52	Leiobin	– 2 –	5 – 2 3 4 2	– 6 7	5 7 7 6	1 1 0 1
4	Pentlon	– – –	– – – – – –	– – 1	– 4 2 4	1 1 1
5	Pomacent	– – –	– – – – – –	3 – –	– 4 – –	1 1 1
13	Priatay	– – –	– – – – – 1	2 3 3	2 – 2 –	1 1 1
15	Upentra	– – –	– – – – – –	2 1 –	– 6 2 –	1 1 1
		0 0 0 / 0 0 0	0 0 0 0 0 0 / 1 1 1 1 1 1 / 0 0 0 0 0 1 / 0 0 0 0 1	1 1 1 / 0 0 0	1 1 1 1 / 1 1 1 1	

Spp cluster 1a

More common and abundant in inner stations

Spp cluster 1b

No clear spatial distribution pattern; Includes ubiquitous species

Spp cluster 2a

Low to moderately abudant species with slight preference for outer stations

Spp cluster 2b

Low to moderately abudant species with somewhat stronger preference for outer stations

Fig. 11 Two-way table output from TWINSPAN showing station and species clusters for the annual spatial analysis of Manila Bay trawl data (1992 - 93).
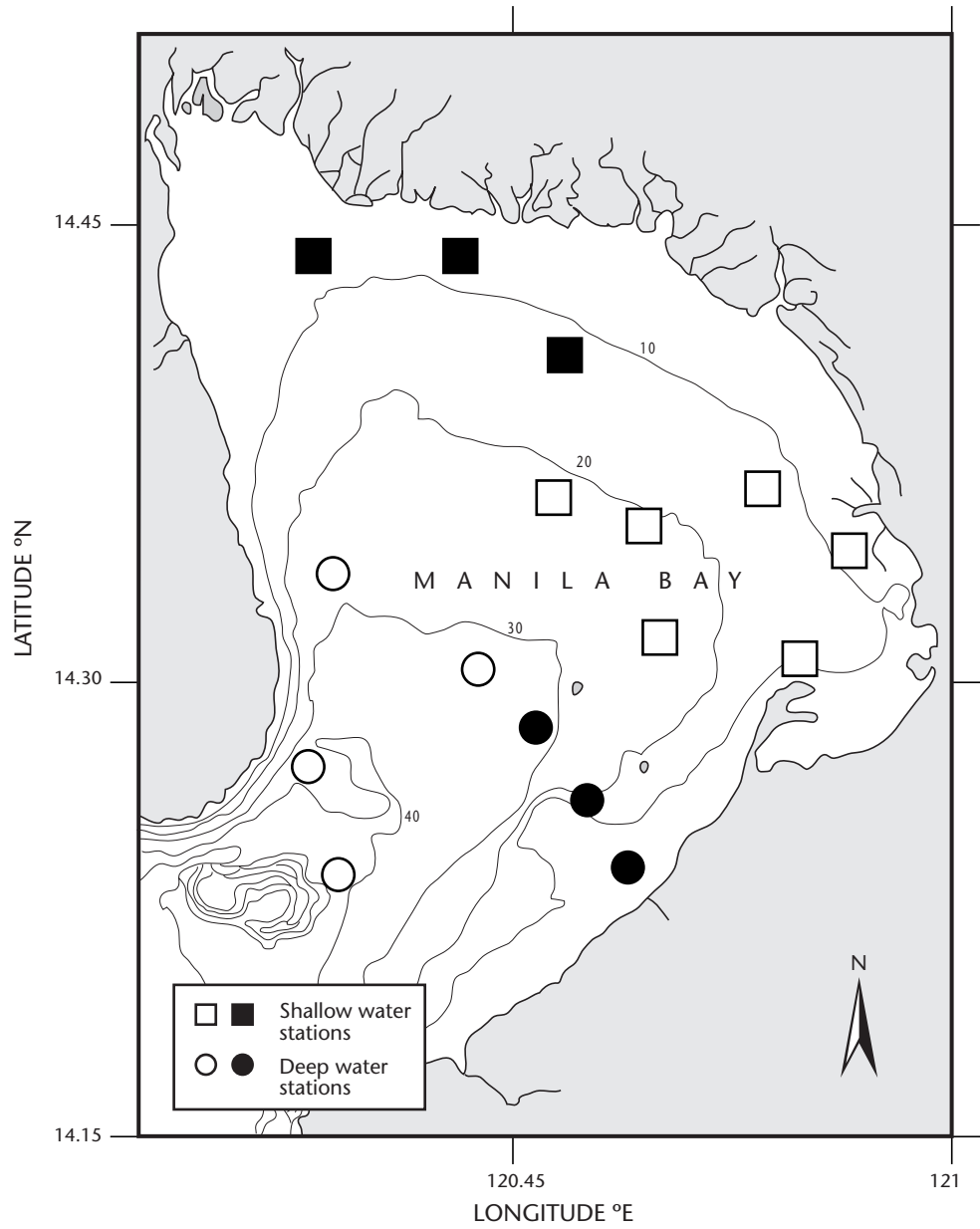
Fig. 12. Map showing location of station clusters formed in the annual spatial analysis of Manila Bay data (September 1992 to October 1993).

```
                    8 9 | 4 5 6 7 | 1 2 3

 7   Crabs(s)       3 3 | – – – – | – – –   0 0 0 0
18   Shrimp         3 – | – – – – | – – –   0 0 0 0          ┌─────────────────────────┐
34   Cynoglos       2 – | – – – – | – – –   0 0 0 0          │ Present only during     │
40   Saurida        3 – | – – – 1 | – – –   0 0 0 0          │ Northeast-ern monsoon   │
53   Charybdi       – 3 | – – – – | – – –   0 0 0 0          │ months                  │
...............................................             └─────────────────────────┘
38   Soleahu        – 2 | – – – 1 | – – –   0 0 0 1 0 0
41   Octopus        2 – | 1 – – – | – – –   0 0 0 1 0 0      ┌─────────────────────────┐
48   Therapon       – 2 | – 1 – – | – – –   0 0 0 1 0 0      │ Moderately abundant     │
17   Shrimp (       – 4 | 1 1 – 2 | – – –   0 0 0 1 0 1      │ during both Northeastern│
21   Goby sp.       4 4 | 3 2 3 2 | – – –   0 0 0 1 0 1      │ & Southwest monsoon     │
26   Gerress        2 3 | – – – 3 | – – –   0 0 0 1 0 1      │ months, but with higher │
12   Sillago        3 4 | – – 2 – | – – 1   0 0 0 1 1        │ abundances              │
- - - - - - - - - - - - - - - - - - - - - - - - - - -       └─────────────────────────┘
15   Seasnake       – – | 2 – – – | – – –   0 0 1 0
19   Sphyraen       – – | – – 1 – | – – –   0 0 1 0          ┌─────────────────────────┐
22   Goby sp.       – – | 1 – – – | – – –   0 0 1 0          │ Absent during transition│
23   Goby sp.       – – | 1 – – – | – – –   0 0 1 0          │ months (Apr - Jul), but │
32   Bukawil        – – | – 1 – – | – – –   0 0 1 0          │ no clear pattern for the│
45   Lagoceph       – – | – – 2 – | – – –   0 0 1 0          │ rest of the year.       │
50   Therapon       – – | – – 2 – | – – –   0 0 1 0          │ Includes uncommon and   │
51   Upeneus        – – | 1 – – – | – – –   0 0 1 0          │ ubiquitous apecies      │
 2   Apogonq        4 4 | 4 4 4 4 | 4 – –   0 0 1 1          └─────────────────────────┘
46   Leiognat       4 3 | 3 4 4 4 | – 1 1   0 0 1 1

20   Triacant       2 – | – – – 1 | – – 1   0 1 0 0
43   Platycep       3 3 | – 1 1 – | 1 1 –   0 1 0 0
49   Therapon       3 – | – 1 – – | – 1 –   0 1 0 0
...............................................
13   Seacucu        – 4 | 3 – 3 – | – – 3   0 1 0 1 0        ┌─────────────────────────┐
28   Platycep       3 2 | 3 3 3 3 | 2 3 –   0 1 0 1 0        │ Species with moderate to│
11   Portunus       4 4 | 3 3 4 3 | 3 3 4   0 1 0 1 1 0      │ high abundances and     │
16   Secutor        2 2 | 3 1 3 – | – 1 3   0 1 0 1 1 0      │ common thro-ughout the  │
31   Brachyrh       3 3 | 4 3 3 3 | 2 3 4   0 1 0 1 1 0      │ year                    │
39   Scorpaen       2 2 | 1 – 2 2 | 1 1 2   0 1 0 1 1 0      └─────────────────────────┘
 8   Pseudorh       3 3 | – – 1 3 | 3 1 –   0 1 0 1 1 1
- - - - - - - - - - - - - - - - - - - - - - - - - - -
 6   Tetraodo       – – | – 3 – 2 | 3 – –   0 1 1            ┌─────────────────────────┐
 9   Pseudorh       – – | 2 2 2 3 | – 2 3   0 1 1            │ Species with low        │
25   Gerress        – – | – 2 2 – | – – 1   0 1 1            │ abundances and present  │
37   Solea sp       – – | – – 2 2 | 1 – –   0 1 1            │ during the Southwest and│
                                                            │ trasition months        │
14   Seas nake      3 2 | 2 – 2 – | – 3 2   1 0              └─────────────────────────┘
36   Sepia sp       – 3 | – 1 – 1 | – 1 2   1 0
 5   Loligos        – – | 3 2 2 – | 4 3 3   1 1 0            ┌─────────────────────────┐
27   Platycep       – – | 1 – – 1 | – – 2   1 1 0            │ Species rarely occurring│
30   Sillago        – – | 1 2 – 2 | 2 2 –   1 1 0            │ during the Northeastern │
55   Cyno glos      – – | – – – 1 | – 1 1   1 1 0            │ months and most common  │
- - - - - - - - - - - - - - - - - - - - - - - - - - -       │ during transition months│
 1   Alectis        – – | – – – – | – – 1   1 1 1            └─────────────────────────┘
 3   Apogonq        – – | – – – – | – 4 4   1 1 1
 4   Gobiidae       – – | – – – – | 4 4 2   1 1 1            ┌─────────────────────────┐
10   Pseudorh       – – | – – – – | – 1 –   1 1 1            │ Species present only    │
24   Gobiidae       – – | – – – – | 3 3 –   1 1 1            │ during tran-sition      │
29   Penaeus        – – | – – – – | 2 3 2   1 1 1            │ months                  │
33   Cynoglos       – – | – – – – | 2 – –   1 1 1            └─────────────────────────┘
35   Squilla        – – | – – – – | – – 2   1 1 1
42   Platycep       – – | – – – – | 1 – –   1 1 1            ┌─────────────────────────┐
44   Platycep       – – | – – – – | 1 – –   1 1 1            │ Northeastern monsoon    │
47   Leiognat       – – | – – – – | 1 –     1 1 1            │ months                  │
52   Penaeus        – – | – – – – | 1 – –   1 1 1            └─────────────────────────┘

                                                            ┌─────────────────────────┐
                    0 0 | 0 0 0 0 | 1 1 1                   │ Southwest monsoon months│
                    0 0 | 1 1 1 1 |                          └─────────────────────────┘

                                                            ┌─────────────────────────┐
                                                            │ Transition months       │
                                                            │ (Apr - Jul)             │
                                                            └─────────────────────────┘
```

Fig. 13. Two way table output for temporal analysis of Sorsogon trawl data. Sampling was monthly April (1) to January (9) (no sampling in May).

```
                      8 4 5 6 2 7 | 1 3 9

13   Red Snap       – 3 3 2 1 –  | – – –    0 0 0
19   Thick-li       – 2 2 – 1 3  | – – –    0 0 0
22   Trumpetf       – 1 – 1 – –  | – – –    0 0 0
15   Redbull        – 3 2 3 1 2  | 1 1 –    0 0 1
20   Groupers       3 2 – – – –  | – – 1    0 0 1
21   Blackpo        – 1 – 2 2 1  | – 1 –    0 0 1

 7   Lizardfi       3 4 3 3 2 3  | 1 2 –    0 1 0
11   Threadfi       3 2 3 2 4 3  | 1 1 1    0 1 0
17   Whitings       2 1 1 3 1 2  | – 1 1    0 1 0
16   Imperial       1 2 3 2 – –  | 1 2 –    0 1 1 0 0
 6   Barracud       – 4 1 3 1 3  | 3 3 1    0 1 1 0 1 0
 1   Slipmout       4 4 4 4 4 4  | 4 4 4    0 1 1 0 1 1
 2   Goatfish       4 4 4 4 4 4  | 3 4 4    0 1 1 0 1 1
 3   Carangid       4 4 3 4 3 4  | 3 4 4    0 1 1 0 1 1
 4   Mojarras       4 3 4 3 2 3  | 2 2 3    0 1 1 0 1 1
 5   Anchovie       4 4 2 3 3 3  | 2 2 –    0 1 1 0 1 1
10   Monocle        2 3 3 3 – 3  | 2 1 3    0 1 1 0 1 1
12   Four-lin       2 3 2 2 2 2  | 1 2 2    0 1 1 0 1 1
26   Crabs          1 1 1 1 1 1  | 1 1 1    0 1 1 0 1 1
 8   Hairtail       – 2 – 2 2 4  | 3 2 –    0 1 1 1
 9   Sardines       3 2 2 2 3 2  | 3 – 2    0 1 1 1
14   Mackerel       2 2 – 1 2 3  | 1 – 2    0 1 1 1

23   Squids         3 3 3 3 3 3  | 3 4 4    1 0
29   Scallops       3 2 1 1 2 1  | 1 4 3    1 0
24   Cuttlefi       – 1 1 1 2 1  | 1 4 –    1 1 0
27   Mantiss        – – 1 – 1 1  | – 4 1    1 1 0
18   Fusilier       – – – – – 1  | 2 – 3    1 1 1
25   Octopus        – – – – – –  | – – 1    1 1 1
28   Penaeid        – – – – – –  | – – 1    1 1 1

                    0 0 0 0 0 0  | 1 1 1
                    0 1 1 1 1 1
                    0 0 0 1 1
```

Species rare during transition months (Oct, Dec & Jun)

Species occurring all year round in comparable abundances. Includes species with high and low abundances

Species most abundant during transition months

← Transition months

↑ Northeastern monsoon months

Fig. 14. Two way table output for temporal analysis of Tayabas Bay data. Sampling was monthly from October (1) to June (9).

Conclusion

The 24 fishing grounds in the exploratory surveys in 1947 - 49 can be arranged in gradients reflecting their substrate make-up (i.e. relative coral cover and sediment characteristics). Catch rate (kg•hr^{-1}) was negatively correlated with both average water depth (-0.48, $p < 0.05$) and mud/sand substrate (-0.51, $p < 0.05$), and reflects an underlying trend of increasing catch rates in areas with shallower and more muddy bottoms. This is also consistent with the distribution of the more abundant families in the catches (e.g. Leiognathidae, Mullidae).

Depth appears to be the primary factor that determines the station clusters in Samar Sea and San Pedro Bay. In San Pedro Bay, catch species composition shows a consistent transition at depths of 15 - 20 m throughout the year. Similarly, Samar Sea shows a transition at the 30 - 40 m depth range, and again at the depths of 50 - 60 m, with further differences in composition between inner (southern) and outer (northern) stations. Manila Bay shows a different pattern; changes in species composition appear to be more related to location (i.e. inner or outer portions) than to depth. Differences in demersal assemblages were observed throughout the year in both inner and outer portions, and between the western and eastern halves of the bay seasonality or within-year differences in species assemblages reflecting the monsoon systems were also evident in Sorsogon Bay and Tayabas Bay.

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