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Spatial structure of demersal fish assemblages in South and Southeast Asia and implications for fisheries management

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Abstract

We provide a review of the assemblage structure of demersal fish resources in four South and Southeast Asian countries. Multivariate techniques (classification and ordination analysis) were used to analyze scientific trawl survey data from a collaborative project in the region. Analyses covered major coastal fishing areas in Bangladesh, Indonesia, Malaysia, and the Philippines. This represents the first such assessment of fish assemblages for the region using a standard analysis framework. Results indicate that spatial patterns of demersal assemblages are influenced by depth. However, other environmental factors such as salinity and substrate type also appear important. Critical fisheries management implications of the observed assemblage patterns are discussed, particularly in terms of the existing spatial management zones. Existing management zones are based on distance from shore and were found to be largely inconsistent with the assemblage patterns observed. If management is to be effective it must be structured to take into account the underlying pattern of the fish assemblages.

Keywords: Demersal fish assemblages; Experimental trawl surveys; Fisheries management; South and Southeast Asia

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1. Introduction

The demersal fishery resources in tropical coastal areas such as those in Asia, consist of highly diverse, multi-species complexes (Longhurst and Pauly, 1987). These fisheries cannot be managed on the assumption they target single species. Therefore, managing the fisheries requires an understanding of the biological assemblage structure. An assemblage is operationally defined as the species available in the same place at the same time (Fauth et al., 1996). Ecological analysis of assemblage structure, since its early application based on vegetation ecology, has become increasingly important in the management of marine resources (McManus, 1997). Assemblage analyses can assist in defining "Assemblage Production Units" (Tyler et al., 1982), which can be used as the basis for assigning particular parts of the fishery to specific groups of fishers, gear types and harvest pressures (McManus, 1997). In addition, these analyses can provide a better understanding of the fundamental patterns of species abundances within harvested ecosystems, assist in identifying the effects of fishing and contribute to developing models to understand the structure of ecosystems (Suvavepun, 1991; McManus, 1997).

In Asia, there has been growing interest in the application of fish assemblage analysis to fisheries (e.g. Fager and Longhurst, 1968; Qui, 1988; McManus, 1986, 1989, 1996; Suvavepun, 1991; Bianchi, 1992, 1996; Chittima and Wannakiat, 1992; Federizon, 1992; Bianchi et al., 1996). In

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Table 1
Previous studies and inferred causes of assemblage structure in tropical Asia (modified from Silvestre et al., 2003)

Region/survey area	Source	Important variables	Analysis method used
Pakistan shelf	Bianchi (1992)	Depth temperature, oxygen values	TWINSPAN (Two-way Indicator Species Analysis), DCA (Detrended Correspondence Analysis)
Northwest coast of Sumatra (shelf region), Indonesia	Bianchi (1996)	Depth	TWINSPAN, DCA
Java Sea (including part of southern South China Sea)	Bianchi et al. (1996)	Depth, associated habitat (estuaries)	TWINSPAN, DCA
Eastern part of the Gulf of Thailand (off Chanthaburi)	Chittima and Wannakiat (1992)	Depth	Similarity index
Ragay Gulf, Burias Pass, Ticao Pass, north of Samar Sea, Philippines	Federizon (1992)	Depth, associated habitats (e.g. coralline areas)	UPGMA (Unweighted Pair-group Method using Arithmetic Averages), TWINSPAN, NMDS (Nonmetric Multidimensional Scaling), CA (Correspondence Analysis)
Sunda continental shelf (off Viet Nam, South China Sea)	Kihara and Itosu (1989)	Season (temporal), depth	Affinity index
Indian Ocean coast of Bali to Mid-Sumatra, Indonesia	McManus (1996)	Depth	TWINSPAN, DCA
Southwest shelf of Indonesia	McManus (1989)	Depth	TWINSPAN
Samar Sea, Philippines	McManus (1986)	Depth	TWINSPAN, DCA
Northern continental shelf of South China Sea	Qui (1988)	Depth	Bray-Curtis measure of similarity
Gulf of Thailand (southwestern part of South China Sea)	Suvavepun (1991)	Temporal, fishing patterns	Spearman's rank correlation of principal species groups

general, these studies have dealt with local or national level analyses of the relationship between environmental parameters and the structure of fish assemblages in the various fishing areas. These studies have also used a wide range of analysis methods (Table 1) making direct comparisons difficult. In most studies, local conditions such as depth, salinity, oxygen depletion and habitat type have been shown to influence the fish assemblage structure (Table 1). However, the regional implications to fisheries management have yet to be given sufficient attention.

Many Asian countries use "fishing zones" as a spatial management tool to restrict fishing in particular areas. These have been established for a range of reasons, including to manage fishing effort or restrict fishing gears to designated areas (Purwanto, 2003), or to avert conflicts that might arise between different fisheries or sectors (e.g. small-scale and commercial sectors) (Barut et al., 2003; Taupek and Nasir, 2003). However, the delineation of these fishing zones is rarely based on a scientific understanding of the spatial structure of the resources. In these cases, the management zones are unlikely to be effective in managing the overall impact from different fisheries on the sustainability of the fish stocks.

Another form of spatial management that has become increasingly common across Asia is the use of marine protected areas (or marine reserves). These can vary from "no take zones" to "multiple-use" areas (Roberts et al., 2001; FAO, 2003; Sale et al., 2005). Marine reserves have been widely promoted as both conservation and fishery management tools, but the fishery benefits remain controversial (Roberts et al., 2001). Again, the underlying assemblage structure is a critical input into the design of a marine reserve, and long-term information on which species persist in reserves of different sizes and assemblage structures is needed to improve their effectiveness (Vanderklift et al., 1998; Botsford et al., 2003).

This paper reviews the results of assemblage structure analyses undertaken within a regional initiative across South and Southeast Asia (Silvestre et al., 2003; Stobutzki et al., 2006). The aim was to examine assemblage structure and infer potential environmental drivers within coastal fishing areas of four countries: Bangladesh, Indonesia, Malaysia, and the Philippines. The analyses use scientific trawl data and standardized analysis techniques to facilitate comparisons and elucidate regional trends in assemblage structure. This is the first time that simultaneous and standardized analyses have been undertaken across multiple countries in the region. Here we present a review of the country-specific and initial regional trends. The critical implications of the spatial structures of fisheries resources to fisheries management and particularly fishing zones are also discussed and we present some topics for future directions for fish assemblage analysis in the region.

2. Materials and methods

2.1. Trawl surveys and data sources

All data came from scientific trawl surveys (Table 2; Fig. 1) and detailed information of the surveys (i.e., sampling design,

Table 2
Fishing areas and surveys used for analysis in understanding demersal fish assemblages in South and Southeast Asia

Country/survey area	Depth (m)	Time period of surveys analyzed	Reference
Bangladesh, Inner Bay of Bengal	10–100	1985	Mustafa (2003)
Indonesia, North Coast of Central Java	5–50	1979	Nurhakim (2003)
Malaysia: West Coast Peninsular Malaysia, East Coast Peninsular Malaysia, Sabah and Sarawak	10–100	1972, 1981, 1987, 1991 and 1997	Alias (2003)
Philippines			Campos (2003)
Manila Bay	10–50	1992–1993	
San Pedro Bay	10–40	1994–1995	
Samar Sea	10–100	1979–1980	

geographic coverage and gear/trawl characteristics) are given in Mustafa (2003) (Bangladesh), Nurhakim (2003) (Indonesia), Alias (2003) (Malaysia), and Campos (2003) (Philippines). The data available were catch of individual species or taxa at each trawl station. There was no standardization between countries in terms of the taxonomic groupings used in the analyses. The data in each country came from different years and surveys were not carried out across seasons, hence the analyses focused on spatial patterns and not inter-annual or seasonal trends.

In all countries, except for Malaysia, the data analyzed were in the form of catch rate (in kg h^{-1}). For Malaysia, catch per unit area (in kg $nmile^{-2}$) was used instead of catch rate. This was done to standardize the data sets used for the analysis since the trawl surveys were carried out in various years (i.e., 1972, 1981, 1987, 1991, and 1997) and to account for differences in the survey coverage area including the types of vessel and gear used for the surveys (Alias, 2003). In addition, species or taxa groups were standardized to family level for consistency between the surveys used in the analysis, and station data belonging to the same grid area in one survey period were averaged for each family. This procedure resulted in a reduction in the number of samples (stations) from 1598 stations to 251 stations to suite the limitations of the TWINSPAN software since it can only accommodate a data matrix containing 400 species with 119 stations/sites (Hill, 1979).

This data reduction procedure may result in a generalization of the spatial structure of the fish assemblages with a possible loss of definition of finer scale distribution patterns of species or taxa.

2.2. Data analysis

Separate analyses were done for each country, each using the same standardized procedure. Patterns of assemblage

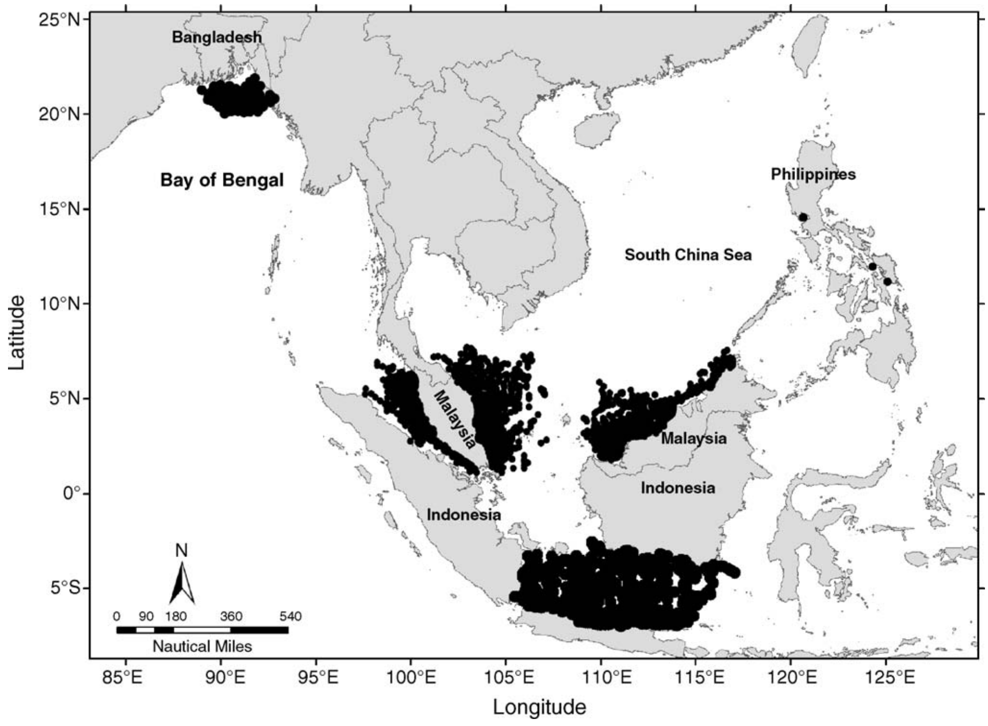


Fig. 1. Locations of study areas (shaded) in Bangladesh, Indonesia, Malaysia, and the Philippines that were analyzed for spatial patterns of demersal fish assemblages.

structure were analyzed using the divisive classification algorithm Two-way Indicator Species Analysis (TWINSPAN) (Hill, 1979). This technique gives the hierarchical relationship between groups of species or stations. To validate the results of the TWINSPAN an ordination was performed using Detrended Correspondence Analysis (DCA). The classification from TWINSPAN and the ordination from DCA are both based on correspondence analysis (van Groenewoud, 1992).

The TWINSPAN produced two-way tables in which the row (species) arrangement corresponds to the species clusters (species assemblages) and the column (sample = station) arrangement corresponds to the sample clusters (i.e., groups of stations forming habitats). In the process, indicator species are identified which are characteristic of the fish assemblage of each group of sample units or station group (Hill, 1979). Dendrograms were then constructed to provide a visual presentation of the similarity or dissimilarity between the formed clusters. TWINSPAN results are usually reasonable at first division, which would explain the first environmental gradients influencing the assemblage patterns (van Groenewoud, 1992). Hence, in most cases we have presented the assemblage groups defined at the first division. In the analysis results for the Malaysian waters, particularly, Sabah and Sarawak area, the second division groups are presented for better resolution since the geographic coverage of surveys were more extensive than in the other areas.

Ordinations were conducted to verify the classification results. Where necessary, a frequency of occurrence of 5–10% was used as criteria to limit the number of species included in the analysis. Ordination of samples (stations) in “species space” and species in “sample space” was performed using 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 geographic location) preferences (sample space). These plots reveal how distinct (or indistinct) the TWINSPAN-generated clusters were from each other. In all countries, the two techniques, i.e., ordination and clustering, produced consistent assemblage grouping.

The relationship between the observed clustering and ordination pattern and environmental parameters (e.g. depth, salinity, substrate type) was examined visually in the country level analysis. Depth information was available for nearly all trawl survey stations, while salinity and substrate information were only available in general areas. To examine the relationship between depth and the fish assemblage groupings more rigorously, a one-way analysis of variance (ANOVA) (Zar, 1984) was undertaken. The ANOVA compared if the mean depths among the assemblage groupings from the ordinations are significantly different. In Sabah/Sarawak, Malaysia, where there were more than two assemblage groups, the ANOVA was followed by the Duncan’s Multiple Range Test (DMRT) (SAS Institute, 1994) to determine which assemblages were significantly different. This analysis was done with the Statistical Analysis System (SAS) software (SAS Institute, 1994).

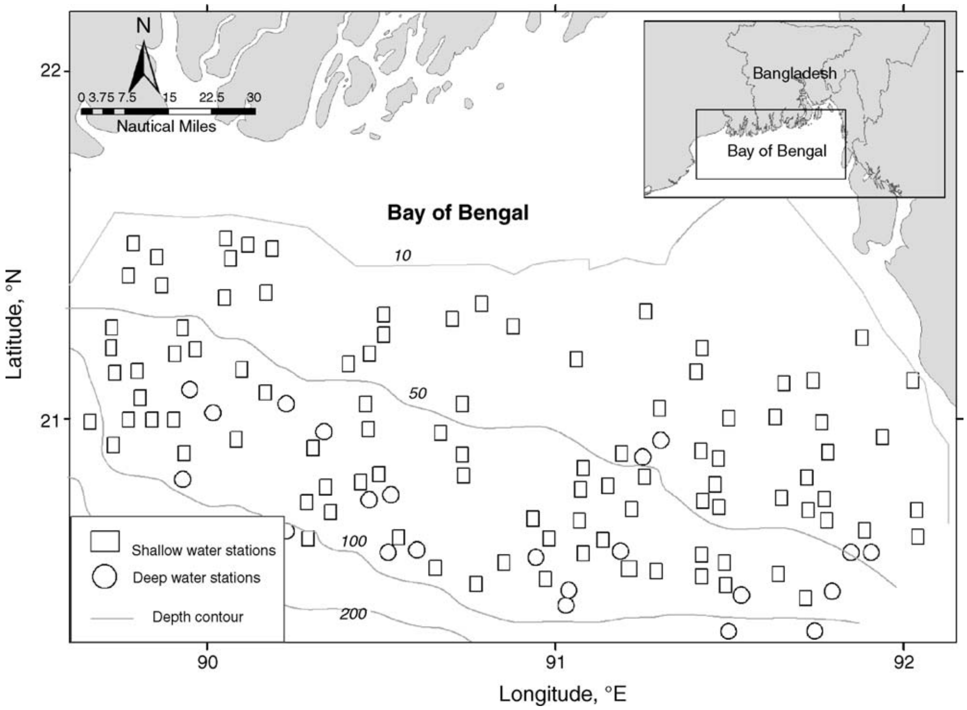


Fig. 2. Map of station locations in the Bay of Bengal, Bangladesh (September 1984–December 1986) showing the geographical delineation of “shallow” and “deep” fish assemblage groups with boundary at approximately 90 m depth contour. Depth is shown in meters (*Source*: Mustafa, 2003).

3. Results

3.1. Bangladesh

The Bay of Bengal waters in Bangladesh showed two assemblage groups. The fishing stations did not show clear delineation between the "shallow-" and "deep-" water assemblages (Fig. 2). However, the mean depths of the "shallow" and "deep" assemblages were significantly different (Table 3). The "shallow" stations were characterized by higher abundances of *Nemipterus japonicus*, *Lepturacanthus savala*, *Pennahia* spp., *Pentaprion longimanus*, *Upeneus* spp., *Arius* spp., *Pomadasys maculatus*, *Thryssa brevirostris*, *Leiognathus bindus*, *Rastrelliger kanagurta*, *Leiognathus* spp. and *Upeneus sulphureus* (Table 4). The "deep" stations were characterized by higher abundances of *Priacanthus hamrur*, *Priacanthus* spp., *Johinus* spp., *Saurida elongata* and *Nemipterus* spp.

Table 3
The average depth and S.E. of stations in each fish assemblage group in each region

Country/survey area	Assemblage groups	Stations (*n*)	Average depth (m)	S.E.	d.f.	*F*	*P*-value
Bangladesh: Inner Bay of Bengal	Shallow	135	71.27	2.43	1, 156	12.48	<0.001
	Deep	23	92.35	2.05			
Indonesia: North Coast of Central Java	Shallow	6	11.67	2.47	1, 16	15.52	<0.001
	Deep	12	27.42	2.34			
Malaysia: West Coast Peninsular	Shallow	32	28.75	1.27	1, 125	147.65	<0.001
	Deep	95	59.53	1.40			
Malaysia: Sabah and Sarawak	Shallow[a]	128	29.93	0.62	2, 378	915.24	<0.001
	Intermediate[a]	178	60.25	1.06			
	Deep[a]	75	114.64	2.25			
Philippines: Manila Bay	Shallow	9	12.78	2.52	1, 14	7.85	<0.01
	Deep	7	27.14	4.86			
Philippines: Samar Sea	Shallow	11	33.18	2.95	1, 26	29.93	<0.001
	Deep	17	64.41	4.15			
Philippines: San Pedro Bay	Shallow	6	13.33	1.05	1, 11	53.71	<0.001
	Deep	7	27.14	1.60			

The results of the one-way ANOVA's comparing depth among assemblage groups are also shown. (*Note*: refer to Fig. 10 and text for assemblage groups by survey area.)

[a] Assemblages groups are significantly different ($P < 0.001$) based on Duncan's Multiple Range Test, see notations on average depth.

Table 4
Distribution of dominant species/taxa comprising the "shallow" and "deep" demersal fish assemblages in South and Southeast Asia

Taxa/Species	"Shallow" fish assemblage							"Deep" fish assemblage						
	BB	NJI	WPM	SSM	MBP	SBP	SSP	BB	NJI	WPM	SSM	MBP	SBP	SSP
Ariidae	X			X							X			
Balistidae														
Abalistes stellatus									X		X			
Carangidae			X	X							X			
Alectis ciliaris												X		
A. indicus						X								
Carangoides armatus							X							
Decapterus kurroides								X			X			
Selaroides leptolepis												X		
Clupeidae				X							X			
Anodontostoma spp.		X	X	X										
Dussumieria elopsoides			X											
Dasyatidae	X										X			
Drepaneidae									X					
Engraulidae		X												
Stolephorus bataviensis					X									
S. commersonnii					X									
S. indicus												X		
Gerreidae		X					X			X				

Table 4 (*Continued*)

Taxa/Species	"Shallow" fish assemblage							"Deep" fish assemblage						
	BB	NJI	WPM	SSM	MBP	SBP	SSP	BB	NJI	WPM	SSM	MBP	SBP	SSP
Haemulidae														
Pomadasys maculatus	X													
Pomadasys spp.									X					
Leiognathidae			X	X						X				
Leiognathus bindus												X		
L. elongatus														
Leiognathus equulus							X							
L. splendens			X				X							
Loliginidae (Squids)			X											
Lutjanidae									X	X				
Mugilidae														
Mugil cephalus					X									
Valamugil seheli					X									
Mullidae			X	X						X	X			
Upeneus sulphureus	X													
U. tragula												X		
Muraenesocidae		X												
Nemipteridae				X				X	X	X	X			X
Nemipterus japonicus	X							X						
Platycephalidae														
Elates ransonnetii													X	
Polynemidae														
Eleutheronema tetradactylum					X									
Pomacentridae												X		
Priacanthidae														
Priacanthus hamrur								X						
P. macracanthus											X			X
Priacanthus spp.										X		X		
Priacanthus tayenus													X	
Sciaenidae	X	X		X	X									
Johnius spp.								X						
Pennahia macropthalmus					X									
Scombridae														
Rastrelliger kanagurta	X		X											
Scomberomorus commerson					X									
Sphyraenidae (Sharks)									X		X			
Sillaginidae														
Sillago sihama					X									
Synodontidae											X			
Saurida elongata								X						
Saurida spp.											X	X		
Synodus variegatus													X	
Tetraogidae														
Neocentropogon aeglefinis											X			
Triacanthidae														
Pseudotriacanthus strigilifer						X								
Trichiuridae														
Lepturacanthus savala	X													
Trichiurus haumela													X	
Trichiurus spp.									X	X				

Note: BB—Bay of Bengal, Bangladesh; NJI—north coast of Java, Indonesia; WPM—West coast, Peninsular Malaysia; SSM—Sabah and Sarawak, Malaysia; MBP—Manila Bay, Philippines; SBP—San Pedro Bay, Philippines; SSP—Samar Sea, Philippines; X—higher abundance.

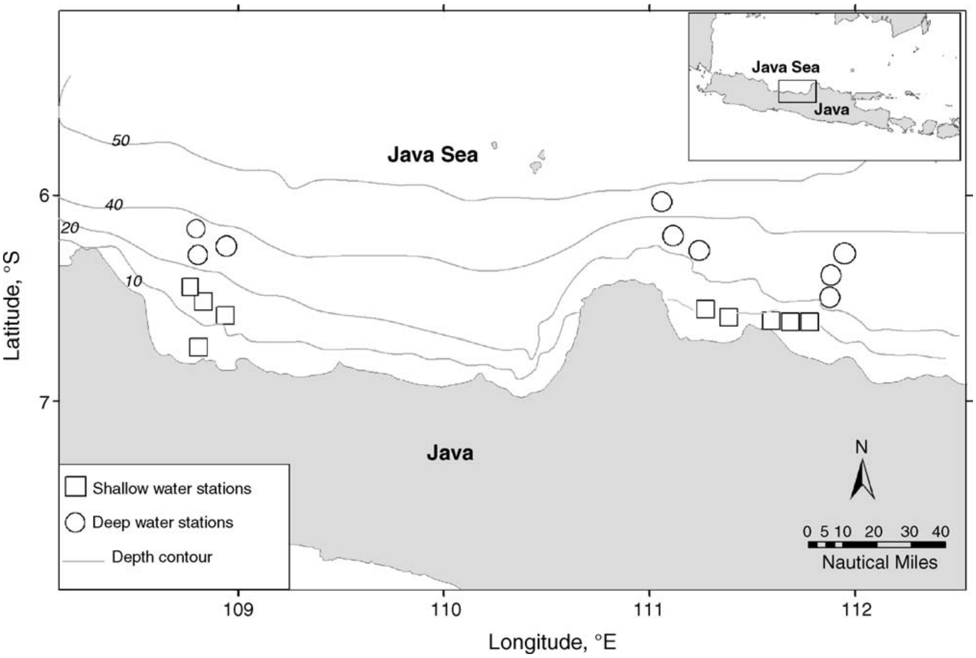


Fig. 3. Map of station cluster locations in Java Sea, Indonesia (January–February 1979) showing the geographical delineation of "shallow" and "deep" fish assemblage groups with the boundary at approximately 20 m depth contour. Depth is shown in meters (*Source*: Nurhakim, 2003).

3.2. Indonesia

Two distinct groups of stations were clearly evident from the analysis in the Java Sea, Indonesia, delineated at 20 m depth (Fig. 3). The mean depth was significantly different between the two assemblage groups (Table 3). There were notable differences in species composition between the "shallow" and "deep" stations. For example, Sciaenidae, Muraenidae and *Anodontostoma* spp. were more abundant in "shallow" water stations while *Priacanthus* spp., *P. longimanus*, Sphyraenidae, *Arius thalassinus* and *N. japonicus* were more abundant in "deep" stations (Table 4).

3.3. Malaysia

The assemblage structure analysis of demersal fish resources in Malaysian waters showed varied results depending on the geographical location. On the west coast of Peninsular Malaysia, there were two (i.e., "shallow" and "deep") assemblage groups, delineated at 50 m depth contour (Fig. 4). On the east coast of Peninsular Malaysia, there was a single assemblage group, which corresponded to the "deep" assemblage of the west coast. There were clear differences in the assemblage groups between Peninsular Malaysia and Sabah and Sarawak areas. In Sabah and Sarawak waters there were three assemblage groups (Fig. 5). The "shallow" group was delineated at 50 m depth, the "deep" group >100 m, and an "intermediate" group between 50 and 100 m. It must be noted that the sampling extended to greater depths (up to 185 m) in Sabah and Sarawak waters than in Peninsular Malaysia (<100 m depth in most stations). Depth differed significantly between the assemblage groups in west coast Peninsular Malaysia as well as in the three assemblages in Sabah and Sarawak waters (Table 3). In terms of species composition, on the west coast of Peninsular Malaysia and in Sabah and Sarawak waters *Anodontostoma* spp., Clupeidae, and Sciaenidae were more abundant in "shallow" stations while *Lutjanus* spp., Dasyatidae and sharks were more abundant in "deep" stations (Table 4).

3.4. Philippines

Three fishing areas were analyzed to understand demersal fish assemblages in the Philippines, namely, the Samar Sea, San Pedro Bay and Manila Bay. San Pedro Bay showed "shallow" and "deep" assemblages with the transition at depths of 15–20 m (Fig. 6). Manila Bay also showed two assemblage groups that appear to be associated with depth, with a transition zone at 40 m depth (Fig. 7). In the Samar Sea, there were also "shallow" and "deep" assemblage groups delineated at 40–50 m (Fig. 8). The "shallow" and "deep" assemblage groups in all of the three study sites in the Philippines were significantly different in depth (Table 3). *Priacanthus* spp. were also abundant in "deep" stations in the three fishing areas studied (Table 4).

4. Discussion

The analyses of trawl surveys in the fishing areas in the South and Southeast Asian countries examined here indicate spatial structuring of the fish assemblages that appears

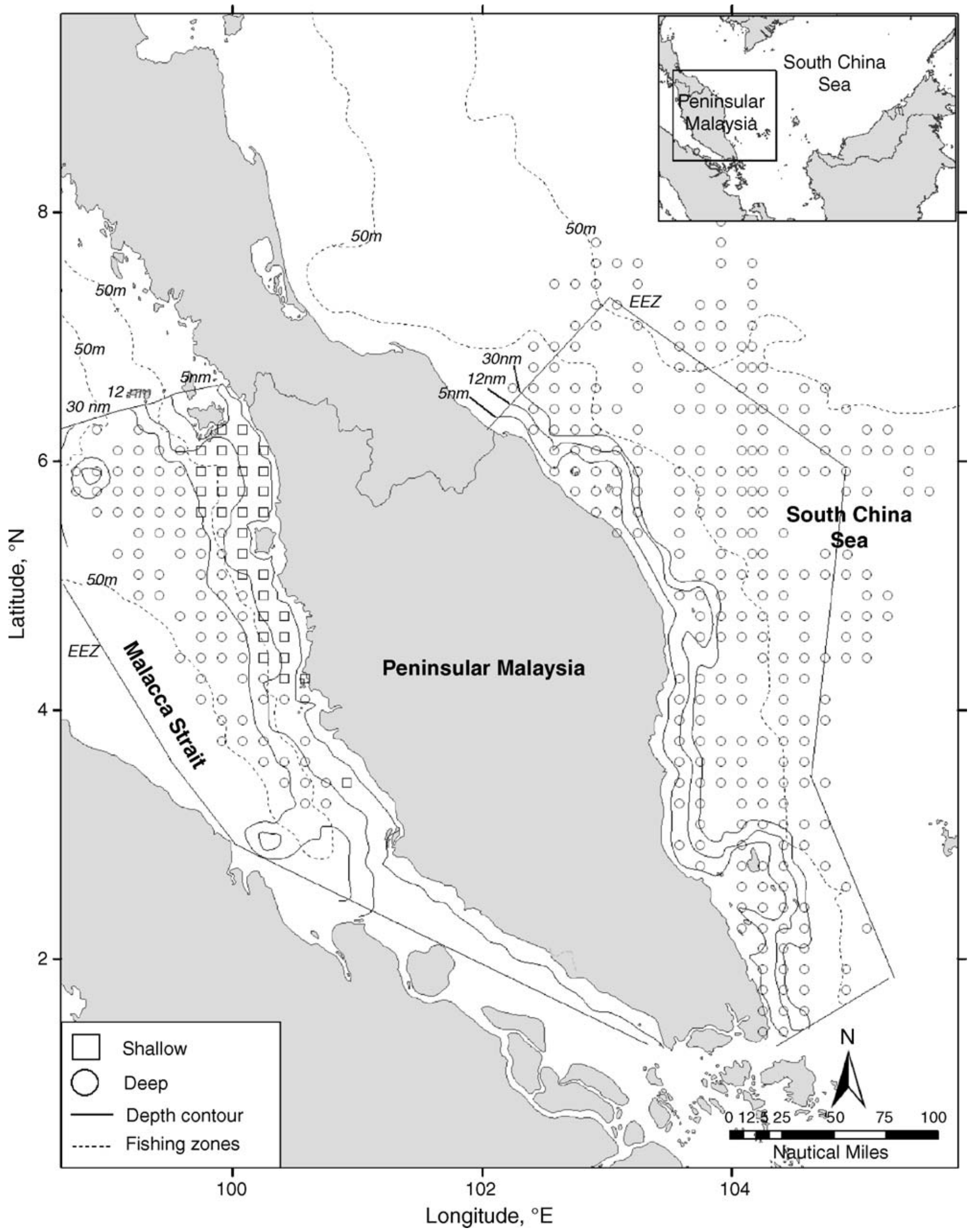


Fig. 4. Map of Peninsular Malaysia showing the geographical delineation of "shallow" (1) and "deep" (2) fish assemblage groups in the west coast with the boundary at approximately 40 m depth contour and a single assemblage in the east coast (*Source*: Alias, 2003). Fisheries management zones in Peninsular Malaysia are also given; the outer boundary represents the EEZ (*Source*: Saharuddin, 1995).

to be influenced by depth (Fig. 9; Table 3). In relatively shallow coastal areas less than 90 m deep two assemblage groups emerge, delineated at 30–50 m. This spatial delineation is consistent with earlier studies (Fig. 10) in the Samar Sea, Philippines (McManus, 1986), Ragay Gulf, Philippines (Federizon, 1992) and northeast coast of Sumatra, Indonesia (Bianchi et al., 1996). For fishing areas deeper than 100 m such as in coastal waters off Sabah and Sarawak, Malaysia, three assemblages were observed: shallow (<50 m), deep (>100 m) and intermediate (50–100 m). Again, this finding is comparable with an earlier study in the northern continental shelf of the South China Sea with delineation at 40, 40–100, 100–200 m (Qui, 1988). Analyses of the catches of 31 of the most common species in a relatively unexploited system in the Gulf of Carpentaria, Australia also indicated that depth strongly affected the abundances of 23 out of 31 species studied (Blaber et al., 1990).

The critical implication of these spatial patterns of demersal fisheries resources is their relationship to existing management zones (Table 5). For example, the waters off Malaysia are subdivided into four zones based on distance from the coastline: Zone A (0–5 nm), Zone B (5–12 nm), and Zone C (12–30 nm), and Zone D (offshore waters extending to the Exclusive Economic Zone boundary) (Saharuddin, 1995).

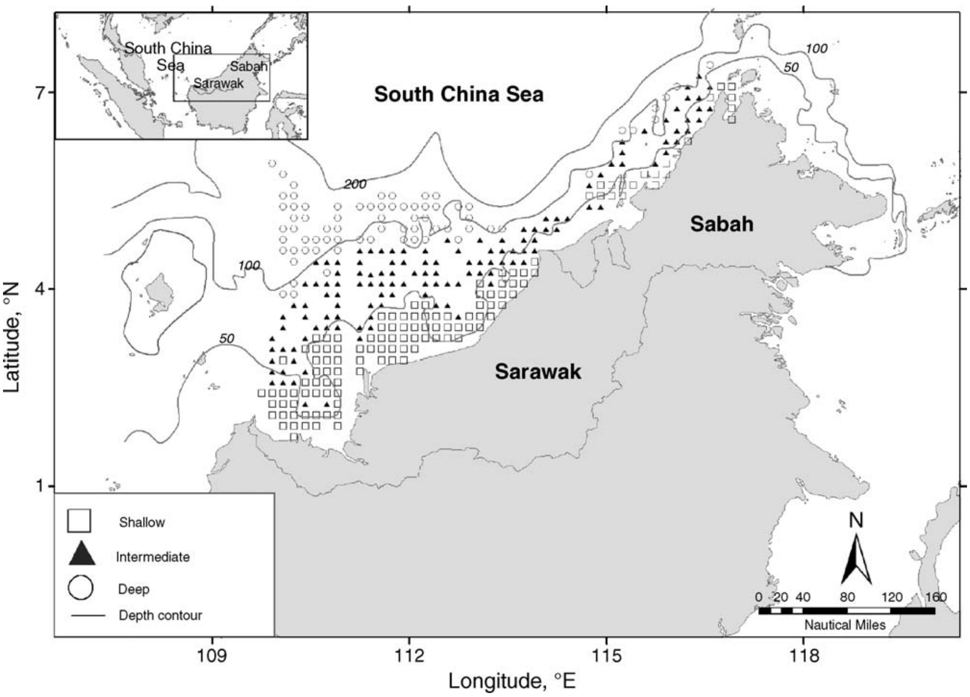


Fig. 5. Map of Sabah and Sarawak Malaysia showing the geographical delineation of "shallow", intermediate, and "deep" fish assemblage groups and delineated at approximately 50 m depth and 100 m depth contour, respectively (*Source*: Alias, 2003).

The existing spatial fisheries management zones are largely inconsistent with the assemblage structure patterns observed in our study. For example, Fig. 4 shows the demersal fish assemblages in Peninsular Malaysia waters based on the analyses and the current management zones being applied to partition fishing effort/gear in the same area. In the case of the Philippines, fisheries are legally categorized into municipal and commercial sectors: the commercial sector is excluded from fishing within 15 km from the shore (Barut et al., 2003). The results of the analyses in three fishing areas: Samar Sea, San Pedro Bay and Manila Bay also indicate that current management zones may not be consistent with the assemblage patterns. It is clear that the demersal fish assemblages go across the management zones and so while different sectors may be segregated spatially they are still potentially fishing the same assemblages and possibly stocks.

Currently, Bangladesh, India, Cambodia and Vietnam have existing management zones based on depth of fishing ground (Table 5). In Cambodia, coastal and commercial fisheries are delineated at 20 m depth, while in Bangladesh artisanal (small-scale) and commercial fisheries are partitioned at 40 m depth. In the southern sector of India fishing zones in the coastal area are delineated at 32, 40, and 70 m. In Vietnam small- and large-scale fisheries are delineated at 30–50 m. The general spatial trends from this study indicated that at this depth range (30–50 m), the "shallow" and "deep" assemblages are delineated and this is consistent with the Vietnamese fishing zones. The Indian fishing zone with specific vessel and gear categories assigned to each zone could also be used as a possible option to partition coastal fisheries (Table 5).

There are no clear patterns in the composition of species/taxa on the assemblage groups (Table 4) since there was no standardization between countries in terms of the taxonomic groupings. However, initial trends indicate some species/taxa such as Sciaenidae and *Anodontostoma* spp. are more abundant in "shallow" stations while "deep" stations are characterized by higher abundances of *Abalistes stellatus*, Lutjanidae, Nemipteridae, *Saurida* spp., *Priacanthus* spp. and *Trichiurus* spp. In an earlier study in the Samar Sea, Philippines, *Leiognathus splendens* and *L. equulus* were suggested as characteristic of a "shallow" subcommunity while "deep" stations characteristically include *Saurida undosquamis*, *Nemipterus nematophorus* and *Priacanthus macracanthus* (McManus, 1986). The results from the current study showed similar species/taxa assemblages for "deep" stations in most of the study areas, however *Leiognathus* spp. showed no clear patterns. In an earlier study on the distribution of leiognathids in Gulf of Carpentaria, Australia (Staunton-Smith et al., 1999), *Gazza minuta*, *Leiognathus decorus*, *L. equulus*, *L. fasciatus*, *L. leuciscus*, *L. smithursti*, *L. splendens*, and *Secutor ruconius* were found to be restricted to coastal areas, whereas *L. bindus*, *L. moretoniensis*, *Leiognathus* sp. and *S. insidiator* were not.

The trends in species composition may also be influenced by habitat structure or substrate. For example, it was noted that on muddy, inshore ("shallow") grounds on Indo-Pacific shelves, where water tends to be turbid, Sciaenidae are more

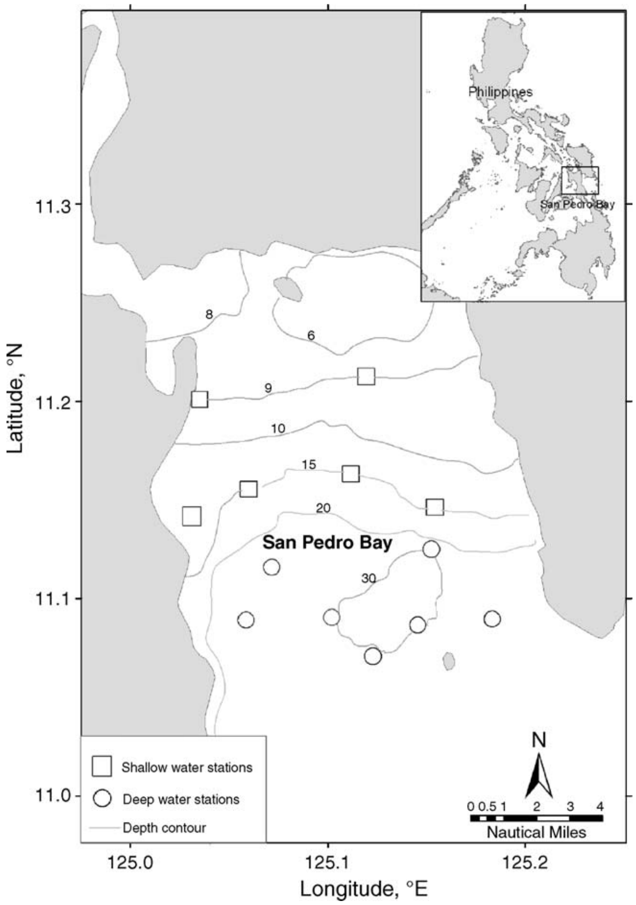


Fig. 6. Map of station cluster locations in San Pedro Bay, Philippines (1994–1995) showing the geographical delineation of “shallow” and “deep” station groups with the boundary at 20 m depth contour. Depth is shown in meters (*Source*: Campos, 2003).

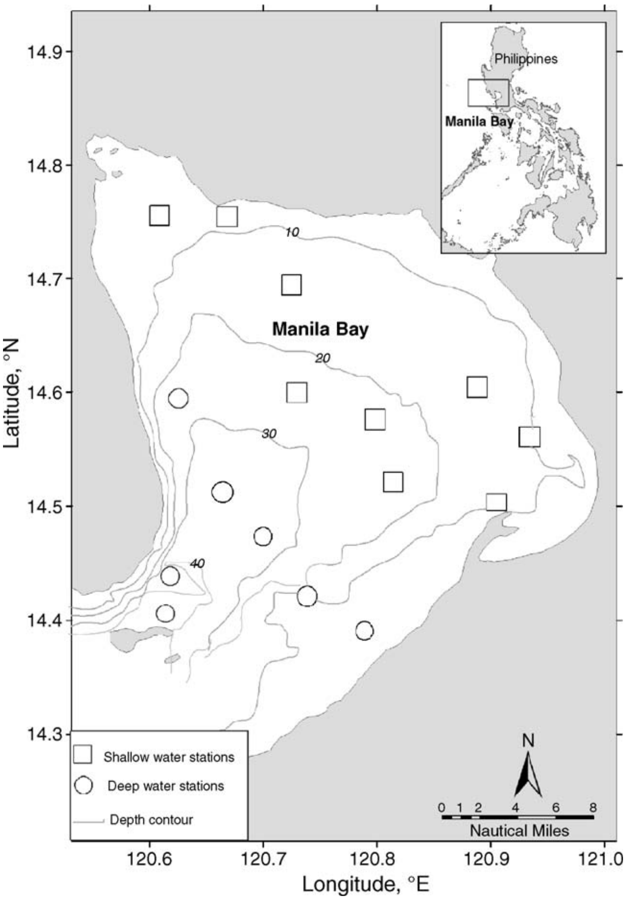


Fig. 7. Map of station cluster locations in Manila Bay, Philippines (1992–1993) showing the geographical delineation of “shallow” and “deep” station groups with the boundary at 20–30 m depth contour. Depth is shown in meters (*Source*: Campos, 2003).

abundant while Pricanthidae, Nemipteridae, Mullidae, Gerridae and Leiognathidae are commoner on sandy grounds (Longhurst and Pauly, 1987). Substrate type could then possibly explain the differences in the four assemblage groupings and between the east and west coast of Peninsular Malaysia. Alias (2003) suggests that the lack of significant coastal mangrove communities on the east coast may be the reason for the lack of a distinct “shallow” assemblage. In addition, Federizon (1992) concluded in the case of Ragay Gulf, Philippines that shallow areas could be further divided into those with soft-bottom and coralline substrate. Moreover, substrate type would have an interaction with depth and distance from the shore. In future analyses of assemblage structure, there is a need to standardize the species groupings across countries to be able to better understand the trends in species/taxa in association with the assemblage groups.

In addition, quantitative analyses with other environmental parameters apart from depth, need to be conducted. Earlier work by Bianchi (1996) and McManus (1996) using the same multivariate methods as the current study (TWINSPAN and DCA) to look at demersal fish assemblages in the eastern Indian Ocean, concluded that salinity, bottom type and depth were the main structuring factors. The relatively unclear transition in the Bay of Bengal (Bangladesh) could be due to oceanographic characteristics such as salinity since it is influenced by a large volume of river discharge (from the Ganges, Brahmaputra and Meghna rivers) into the Bay of Bengal (Mustafa, 2003). Moreover, there were differences in the species composition between inner (southern) and outer (northern) stations in “deep” stations in the Samar Sea, Philippines (Campos, 2003). The differences in the species composition in the “deep” stations could be attributed also to differences in habitat or substrate type, salinity structure and other physical characteristics (i.e., wave action) of the fishing grounds (e.g. Manila Bay and San Pedro Bay) resulting in two assemblage groups.

Apart from spatial structure, there is also a need to look into the temporal stability of the assemblages. Inter-annual trends in species/taxa assemblages were reported within each of the countries studied here (Alias, 2003; Campos, 2003; Nurhakim, 2003; Srinath et al., 2003). However, we could not compare temporal trends as trawl data in the different coastal fishing areas and the countries covered came from different years and seasons. Preliminary results from the Philippines

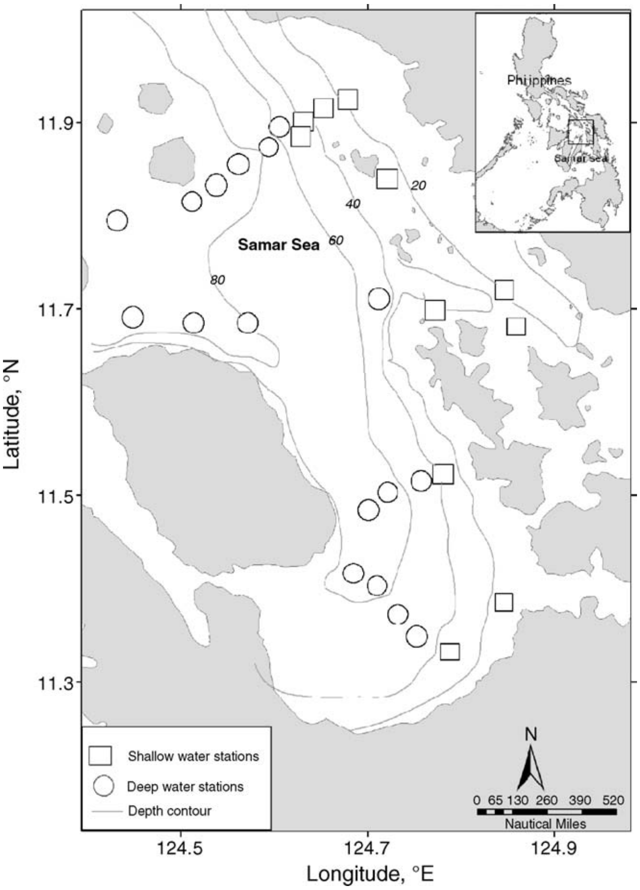
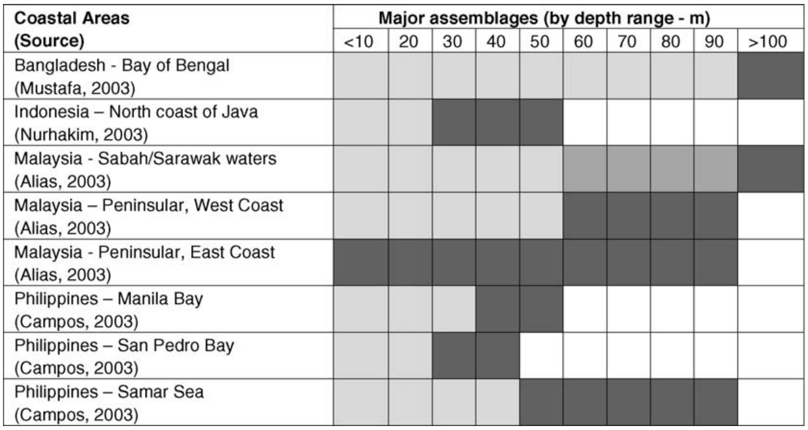


Fig. 8. Map of station cluster locations in Samar Sea, Philippines (March 1979–May 1980) showing the geographical delineation of "shallow" and "deep" station groups with the boundary at 30–40 m depth contour. Depth is shown in meters (*Source*: Campos, 2003).

indicated that the deeper boundaries (e.g. 40–60 m) were temporally stable and that the shallower depths (10–30 m) were seasonally influenced (Campos, 2003). This is consistent with the limited number of assemblage structure studies conducted previously in the region (Federizon, 1992; Bianchi, 1996; McManus, 1996). In addition, potential effects of the monsoon system on the distribution of demersal resources need further understanding (Campos, 2003). Before management zones can be based on the assemblage structure, there is a need to understand the temporal stability of these assemblages. Data availability could be a constraint for this type of analysis since fishing usually ceases during monsoon seasons as well as the conduct of scientific trawl surveys.

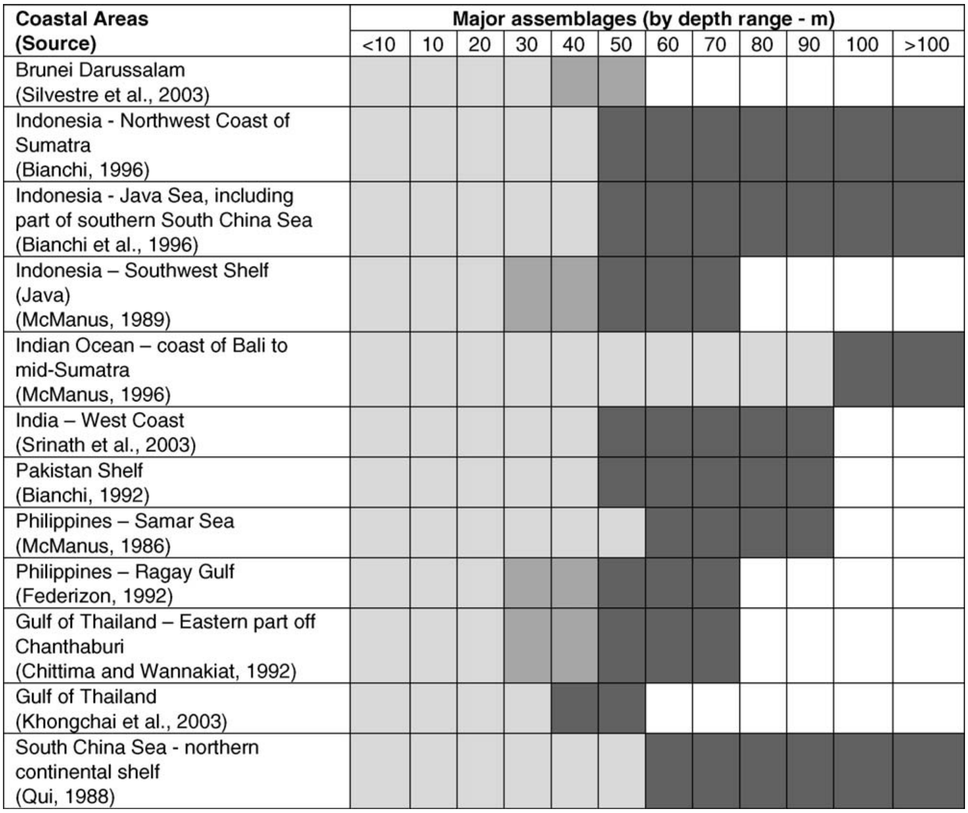
Assemblage analyses could also provide insights into the human-induced changes (which include the impact due to fishing), the duration of impact, and the succeeding recovery of the communities (Watson et al., 1990). The assemblages examined here have all been subject to fishing and other human impacts. The extent of influence of this on the detected structure is unknown. In an earlier study in the Gulf of Thailand, it has been shown that fishing can affect, directly or indirectly, the structure of fish assemblages (Suvavepun, 1991). In addition, heavy fishing pressure may have changed the species composition of demersal fish communities and the macrobenthos (Kongprom et al., 2003; Christensen, 1998). Evidence for massive changes in species composition in the Gulf of Thailand was obtained from analysis of trawl survey data between 1963 and 1972 (Pauly, 1988). The study noted a faster decrease in abundance of Leiognathidae and some other small fishes as well as virtual disappearance of Pristidae and Dasyatidae (i.e., very large, long-lived fish). Temporal analyses of the assemblage structure, where data are available from prior to or the early years of fishing, would help elucidate the changes that have occurred.

In current study, the multivariate techniques were standardized across the countries to allow comparisons. However, this restricted the approaches that could be used and therefore limits the results obtained. TWINSPAN analysis, has been noted to be most reliable for the first division and should be restricted to sampling across a single gradient or prestratifying the samples (or stations) to represent one gradient at a time (van Groenewoud, 1992). In some of the country analyses, for example, Java Sea (Nurhakim, 2003), the



Coastal Areas (Source)	Major assemblages (by depth range - m)									
	<10	20	30	40	50	60	70	80	90	>100
Bangladesh - Bay of Bengal (Mustafa, 2003)	░	░	░	░	░	░	░	░	░	▓
Indonesia – North coast of Java (Nurhakim, 2003)	░	░	▓	▓	▓					
Malaysia - Sabah/Sarawak waters (Alias, 2003)	░	░	░	░	░	▒	▒	▒	▒	▓
Malaysia – Peninsular, West Coast (Alias, 2003)	░	░	░	░	░	▓	▓	▓	▓	
Malaysia - Peninsular, East Coast (Alias, 2003)	▓	▓	▓	▓	▓	▓	▓	▓	▓	
Philippines – Manila Bay (Campos, 2003)	░	░	░	▓	▓					
Philippines – San Pedro Bay (Campos, 2003)	░	░	▓	▓						
Philippines – Samar Sea (Campos, 2003)	░	░	░	░	▓	▓	▓	▓	▓	

Fig. 9. Summary of the major fish assemblage boundaries observed from assemblage structure analysis in South and Southeast Asia. The different shading in each area depicts the different fish assemblages from the analyses. Depth ranges with no shading were not covered by the survey or analysis (Mustafa, 2003; Nurhakim, 2003; Alias, 2003; Campos, 2003).



Coastal Areas (Source)	**Major assemblages (by depth range - m)**											
	<10	10	20	30	40	50	60	70	80	90	100	>100
Brunei Darussalam (Silvestre et al., 2003)	░	░	░	░	▒	▒						
Indonesia - Northwest Coast of Sumatra (Bianchi, 1996)	░	░	░	░	░	▓	▓	▓	▓	▓	▓	▓
Indonesia - Java Sea, including part of southern South China Sea (Bianchi et al., 1996)	░	░	░	░	░	▓	▓	▓	▓	▓	▓	▓
Indonesia – Southwest Shelf (Java) (McManus, 1989)	░	░	░	▒	▒	▓	▓	▓				
Indian Ocean – coast of Bali to mid-Sumatra (McManus, 1996)	░	░	░	░	░	░	░	░	░	░	▓	▓
India – West Coast (Srinath et al., 2003)	░	░	░	░	░	▓	▓	▓	▓	▓		
Pakistan Shelf (Bianchi, 1992)	░	░	░	░	░	▓	▓	▓	▓	▓		
Philippines – Samar Sea (McManus, 1986)	░	░	░	░	░	░	▓	▓	▓	▓		
Philippines – Ragay Gulf (Federizon, 1992)	░	░	░	▒	▒	▓	▓	▓				
Gulf of Thailand – Eastern part off Chanthaburi (Chittima and Wannakiat, 1992)	░	░	░	▒	▒	▓	▓	▓				
Gulf of Thailand (Khongchai et al., 2003)	░	░	░	░	▓	▓						
South China Sea - northern continental shelf (Qui, 1988)	░	░	░	░	░	░	▓	▓	▓	▓	▓	▓

Fig. 10. Summary of the major assemblages resulting from previous community structure studies in Tropical Asia (Adapted from Silvestre et al., 2003). The different shading in each area depict the different fish assemblages determined from the analyses. Depth ranges with no shading are not covered by the survey or analysis (Bianchi, 1992, 1996; Bianchi et al., 1996; McManus, 1986, 1989, 1996; Srinath et al., 2003; Federizon, 1992; Chittima and Wannakiat, 1992; Khongchai et al., 2003; Qui, 1988).

Table 5
Spatial delineation of small and large-scale fisheries in Asia based on existing legal legislation

Countries	Reference point: distance from shoreline				Source/reference
	Fishing Zone I	Fishing Zone II	Fishing Zone III	Fishing Zone IV	
Brunei Darussalam	Shore to 3 nm (small-scale fisheries)	3–20 nm (small-scale fisheries and industrial fisheries: trawlers <350 HP; purse seiners <20 m LOA)	20–45 nm (small-scale fisheries and industrial fisheries: trawlers with 350–550 HP; purse seiners with 20–30 m LOA)	45 nm to EEZ limit (small-scale fisheries and industrial fisheries: purse seiners >30 m LOA)	Silvestre and Matdanan (1992), SEAFDEC (1999)
Indonesia	Shore to 3 nm (small-scale fisheries and fishing vessel <5 GT/10 HP	7 nm (small-scale fisheries and fishing vessel <25 GT/50 HP)	12 nm (industrial fisheries and fishing vessel <100 GT/200 HP)	>12 nm (industrial fisheries fishing vessel >100 GT/200 HP)	Purwanto (2003)
Malaysia	Shore to 5 nm (traditional fisheries, owner operated vessels)	5–12 nm (commercial fisheries, for owner-operated trawlers and purse seines <40 GT)	1230 nm (commercial fisheries, for trawlers and purse seines >40 GT, wholly owned and operated by Malaysian fishers)	30 nm to EEZ (commercial fisheries, for deep sea fishing vessels of >70 GT)	Saharuddin (1995), Abu Talib and Alias (1997)
Myanmar	5 nm in the northern area; 10 nm in southern area (coastal fisheries: boats of <30 feet or using <12 HP)	Outer limit of fishing zone to EEZ limit (industrial fisheries: boats of >30 feet long or using >12 HP engines)	–	–	SEAFDEC (1999)

Table 5 (*Continued*)

Countries	Reference point: distance from shoreline				Source/reference
	Fishing Zone I	Fishing Zone II	Fishing Zone III	Fishing Zone IV	
Philippines	15 km (municipal fisheries: using fishing vessels <3 GT or fishing not requiring the use of fishing vessels)	15 km to EEZ limit (commercial fisheries: Small-scale – with passive or active fishing gear utilizing fishing vessels >3.1 GT	–	–	Barut et al. (2003), Philippine Congress (1998)
Thailand	Shore to 12 nm (small-scale fisheries with boats <5 GT)	12 nm to EEZ limit (large-scale fisheries with boats >5 GT)	–	–	SEAFDEC (1999)
Bangladesh	Shore to 40 m depth (traditional/Artisanal fisheries)	>40 m to EEZ (commercial fisheries)	–	–	Rahman et al. (2003)
India	Northern sector: shore to 16 m depth Southern sector: shore to 32 m depth, Artisanal craft/traditional gears	Northern sector: 16–20 m depth Southern sector: 32–40 m depth, motorized craft using traditional gear	Northern sector: 20–40 m depth Southern sector: 40–70 m depth, small mechanized: vessels <25 GRT	Deep sea fishing, vessels >25 GRT and engine >120 HP	Vivekanandan et al. (2003)
Cambodia	Shore to 20 m depth (coastal fisheries boat without engine or with engine from 5 to 50 HP)	20 m to EEZ limit (commercial fisheries with boat engine >50 HP)	–	–	SEAFDEC (1999)
Vietnam	Shore to 30 m depth in Northern and Southern areas, to 50 m depth in Central area (small-scale fisheries with boats with no engine and with engine <40 HP)	30–50 m depth to the EEZ limit (large-scale fisheries and boats with engine >40 HP)	–	–	SEAFDEC (1999)

Based from Silvestre et al., 2003.

data sets were analyzed separately by season (i.e., pre- and post-monsoon) to rectify this problem. The emergence of a single assemblage on the east coast of Peninsular Malaysia may be attributed to the analysis approach undertaken by Alias (2003). The Malaysia data was pooled across survey years and this may not have taken into account some seasonality or temporal trends. It would be valuable to use other analysis tools or software to validate the results more thoroughly. For example, canonical correspondence analysis (CCA), performs quite well with skewed species distributions, quantitative noise in species abundance data, samples taken from unusual sampling designs, highly inter-correlated environmental variables, and in situations where not all of the factors determining species composition are known (Palmer, 1993).

5. Conclusions

Assemblage analyses have the potential to provide valuable inputs into fisheries management, particularly in multispecies fisheries, such as the trawl fishery in South and Southeast Asia. They can assist in: (i) determining geographical or spatial boundaries of fish assemblages (Tyler et al., 1982; McManus, 1986, 1997); (ii) subdividing fisheries into components subjected to simultaneous conditions, e.g. effect of fishing pressure (Suvavepun, 1991), and changes in environmental conditions (Kihara and Itosu, 1989); (iii) design management interventions to partition different fisheries or gears based on spatial patterns of fish assemblages. This paper provides an example of a regional project, in which standardized analyses framework was used, enabling cross-country comparisons. This has clearly shown consistent trends in the coastal fish assemblages, with spatial structuring present in all areas and depth as a potential driving factor. Based on this, we have raised concern regarding the existing spatial fisheries management zones, most of which are based on distance from shore and have not taken into account the assemblage structure. In order to effectively manage fishing effort on assemblages, the spatial structuring needs to be taken into account in delineating these zones. The existing fishing zones in Vietnam for example, which are based on depth, coincided with assemblage delineation shown here (i.e., 30–50 m). In order to manage the overall impact from different fisheries, gears or sectors, the delineation of management zones to partition fishing effort, needs to take into account the spatial patterns of resources. Based on the regional trends seen here, the fishery resources are delineated by depth at 30–50 m and at about 90–100 m. Management should examine how depth could be used as basis for revising the existing fishing zones rather than just distances from the shore. In terms of practicality, distance from shore may be easier to enforce, but the distance could be equated with the relevant depths and assemblages.

Finally, there would be substantial benefit in further regional analyses of assemblage structure, using the available scientific trawl survey data and related information. These should focus on: (1) local and regional changes in assemblages through time to determine temporal stability and examine the impact of anthropogenic effects, particularly fishing (e.g. the work of Pauly, 1988; Suvavepun, 1991); (2) using the spatial assemblage patterns in the construction and articulation of spatially-explicit ecosystem models and tools to describe their functioning and likely responses to changes in fishing pressure; (3) provision of scientific insights to assist in the management of marine resources and biodiversity conservation including identifying conservation areas for species or stocks based on their spatial distribution and abundances, e.g. site selection of marine protected areas or fish sanctuaries.

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