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PATTERNS OF FISH ASSEMBLAGES ON CORAL REEFS OF THE ADANG-RAWI ISLANDS, THE ANDAMAN SEA, WITH COMMENTS ON MANAGEMENT IMPLICATIONS FOR CORAL REEF RESERVES

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ABSTRACT

Fish communities on coral reefs of the Adang-Rawi Islands group were investigated in February and November 1998. A preliminary checklist containing the records of 375 species in 60 families of fishes is provided. A semi-quantitative census method was used to assess the abundance of fish species at 26 stations from 15 reef sites. Fish community structure is compared between reef flat and reef slope stations using both a direct comparison of population parameters and multivariate statistical techniques, i.e. classification and MDS ordination. In general, reef slope supports higher species richness and abundance of fishes than does the reef flat. Multivariate methods indicate a clear distinction between the assemblages of fishes in the two reef zones. Characteristic fish fauna in each reef zone is described and the striking difference in composition of fishes between the two zones is emphasized with respect to their trophic structures. These reveal the supportive roles of habitat zones in coral reefs to a range of ecological niches of fishes. Attention has also been drawn to a need for establishment of multiple use management for the Adang-Rawi Islands group. Logical criteria (i.e. biological diversity, reef conditions and geomorphological features of the reefs) for choosing suitable coral reef reserves are recommended.

Key words: fish assemblage, coral reef, management implications, marine reserve, Tarutao Marine National Park, Andaman Sea

INTRODUCTION

The Adang-Rawi Islands group is a part of the Tarutao Marine National Park. The island group consists of two large islands, i.e. Ko Adang and Ko Rawi (maximally (Fig. 1) about 8–10 km across), three moderate-sized islands, i.e. Ko Butang, Ko Lipe and Ko Bitsi (1.5–3 km), and some 15 small islands only a few hundred meters across. Within the area, coral reefs exhibit a major coastal feature. In the past, the reef areas were severely to moderately damaged by several types of disturbances, namely blast-fishing, crown-of-thorns starfish infestation, and storms (PHONGSUWAN & CHANSANG, 1987; PHONGSUWAN *ET AL.*, 1993; OCHIENG ET AL., 1997). Most reefs are presently still in the process of recovery (PHONGSUWAN, 1999).

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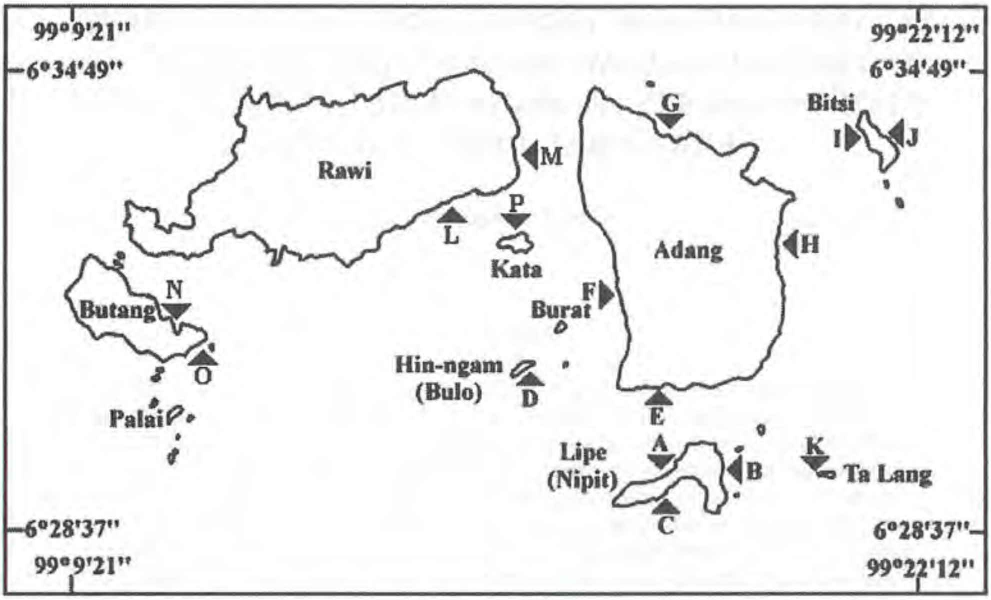

Figure 1. Map of the Adang-Rawi Islands indicating the location of sampling site A–P to each island.

The local inhabitants, particularly sea-gypsy villagers, have earned their lives mainly on fishery resources. Fishing operations have been made either directly in the reef area or in the sea nearby. Several common fishing activities in the area include trapping, trolling, hook-and-line fishing, netting and shell collecting. Commercial fisheries, notably otter trawlers, purse seiners, and squid lift-netters, are also conducted around the island group by mainland fishermen. At present, although there is still no direct indication of over exploitation of fishery resources within the area, the development of a communal fishing system which is dependent upon a few investors and a big demand on fishery products for export may bring about a substantial increase in fishing intensity. The present study aims at providing a baseline status of reef fish resources of the Adang-Rawi Islands group, which should be of use for future zoning and management planning for a proper use of reef resources in the area.

MATERIALS AND METHODS

Fish Collection

Collections of fish specimens were conducted along the northwest coast of Ko Lipe. There were 3 collections on rocky shore (in rock and sand pools), 3 collections on reef flat and 1 collection on reef slope. A 10% quinoline solution was used as an ichthyocide in 2 collections on rocky shore, 3 collections on reef flat and 1 collection on reef slope. All except the last were conducted at low tides when the area was exposed and fishes were stranded in tide pools. Another collection in rocky shore areas was conducted during rising tide at night by using a hand net.

Table 1. List of information on sampling location, dates, and depth for the fish survey at the Adang-Rawi Islands. *Note that depth in bracket is related to the chart datum (lowest low water).

Location	Site code	Reef zone	Date	*Depth in meter
Ko Lipe/NW	A	reef flat	10 Feb. 98	3.3 (1.6)
		reef slope	10 Feb. 98	6.1–7.6 (5.3–6.8)
Ko Lipe/E	B	reef flat	12 Feb. 98	1.5–3.0 (0.1–1.6)
		reef slope	13 Feb. 98	10.6–11.5 (9.1–10.4)
Ko Lipe/S	C	reef flat	11 Feb. 98	3.0 (0.8)
		reef slope	11 Feb. 98	7.6–10.6 (6.2–9.2)
Ko Hin-ngam/S	D	reef slope	15 Feb. 98	3.6–5.2 (2.0–3.6)
Ko Adang/S	E	reef flat	14 Feb. 98	3.0 (1.2)
		reef slope	14 Feb. 98	6.1–7.6 (4.7–6.2)
Ko Adang/W	F	reef flat	12 Feb. 98	2.4 (0.6)
		reef slope	13 Feb. 98	7.6–9.1 (5.6–7.1)
Ko Adang/N	G	reef slope	17 Feb. 98	6.7–7.6 (5.0–5.9)
Ko Adang/E	H	reef flat	16 Feb. 98	2.4–3.0 (0.1–0.7)
		reef slope	15 Feb. 98	6.1–7.6 (3.9–5.4)
Ko Bitsi/W	I	reef slope	18 Feb. 98	5.4–6.1 (3.2–3.9)
Ko Bitsi/E	J	reef flat	17 Feb. 98	2.4–3.0 (0.2–0.8)
		reef slope	18 Feb. 98	4.5–6.1 (3.1–4.7)
Ko Rawi/S	L	reef flat	10 Nov. 98	2.0 (0.0)
		reef slope	11 Nov. 98	3.0–4.0 (2.9–3.9)
Ko Rawi/E	M	reef flat	11 Nov. 98	2.0 (0.2)
		reef slope	12 Nov. 98	6.5–10.0 (5.1–8.6)
Ko Butang/NE	N	reef flat	13 Nov. 98	2.0 (0.3)
		reef slope	12 Nov. 98	4.0–6.5 (3.0–5.5)
Ko Butang/SE	O	reef flat	13 Nov. 98	2.0 (0.5)
		reef slope	13 Nov. 98	6.5–8.0 (4.3–6.8)
Ko Kata/N	P	reef slope	10 Nov. 98	5.0–6.0 (4.0–5.0)

Before this sampling program, a general survey of fishes in the island group had been made in December 1994. The surveys were conducted by sighting and collecting fish specimens using ichthyocide (tea-seed powder extracts, 5 collections) and gill nets (2 collections) at various reef sites including Ko Lipe, Ko Rawi, Ko Kata and Ko Butang. The data from that survey have been compiled in the present checklist.

Fish Census Survey

The surveys were carried out at 10 reef sites (A–J) in February 1998 and at the other 5 sites (L–P) in November 1998 (Fig. 1 & Table 1). Note also that the quantitative census survey was not made at the reef site K (at Ko Talang) because the reef is merely developed as a small patch reef. This site code, however, was retained in order to insure that all the assigned codes accorded with other studies (e.g. corals and giant clams) in the same sampling program. At all sites, except the sites D, G, I and P where the reefs were not divided into discrete geomorphological zones, the assessment of species composition and abundance of fishes was made separately for two reef zones, namely reef slope and reef flat. For each sampling occasion, fish abundance was assessed using a visual census technique (ENGLISH *ET AL.*, 1994). Five replicates of 30-m long transects were laid on reef face running parallel to shore or keeping the line at a consistent depth. Replicate transects were set about 20 m apart. An assessment of abundance of fish species was made within the range of approximately 5 m either side (as a 10-m belt transect) and above the transect line. All conspicuous and visually obvious fishes excluding those with cryptic and/or burrowing behavior (e.g. Blenniidae, Gobiidae, Tripterygiidae, and others) were estimated. While conducting a census dive, swimming path was in a zigzag pattern to allow coverage of the entire area. The cumulative abundance of each fish species found in the census area was estimated semi-quantitatively following a $\log_4$ abundance scale. The scale included the abundance categories from 1 to 7: Category 1 = 1 fish observed; Category 2 = 2–4; Category 3 = 5–16; Category 4 = 17–64; Category 5 = 65–256; Category 6 = 267–1,024; and Category 7 = 1,025–4,096.

Data Analysis

For interpretation of the numerical abundance value, the mid-point of each log abundance category was used as the best estimate of abundance of species, except in the category 7 in which the lowest quartile of the category range (1,025) was used (ENGLISH *ET AL.*, 1994). For each sampling belt-transect the numbers of species and individuals of fishes were calculated per plane area of 300 m^2.

Multivariate statistical procedures were adopted for community-level analysis. A hierarchical agglomerative classification was used to determine the fish assemblage patterns. Prior to the analysis the numerical abundances of each species among the 5 replicate-transects were pooled and averaged to obtain a single transect estimate for each station. The abundance was re-assigned the nearest class mean $\log_4$ value on the abundance scale. These values (range 1–7) for species of all stations (sites/zones) were used to compute a dissimilarity matrix (as Euclidean distances), and unweighted pair-group average linkage was used to determine the cluster. Multi-dimensional scaling (MDS) ordination was also performed on the same dissimilarity matrix. For between-zone comparisons, the nonparametric Mann-Whitney U-test was used to determine the significance of differences in species richness, total abundance, and abundance of selected species.

RESULTS

Checklist

A total of 375 species belonging to 60 families of fishes have been identified based on this study and my earlier survey conducted in December of 1994 (Appendix). Of this total, up to 70 species had never been recorded in any of my previous surveys (SATAPOOMIN, 1993, 1997, 1999; SATAPOOMIN & CHANSANG, in press) conducted on coral reefs along the Andaman Sea coast of Thailand, and 40 of these represent new records for the area. About 70% of the total number of species includes the top 13 most speciose families, namely Gobiidae (53 species), Pomacentridae (44 species), Labridae (43), Apogonidae (17), Serranidae (16), Chaetodontidae (15), Blenniidae (14), Scaridae (13), Lutjanidae (12), Acanthuridae (9), Holocentridae (8), Muraenidae (8), and Scorpaenidae (8). Species lists of these families are likely to represent a majority of species to be found on coral reefs of the Adang-Rawi Islands group. However, before a reasonably complete list of the fish fauna of this reef system can be accomplished, much further comprehensive collection, applying various types of sampling techniques, is required. Between the two defined geomorphological zones on reef (reef flat and reef slope), a greater diversity of fish species was found on the reef slope (309 species) compared with the reef flat (198 species).

Fish Species and Abundances

In all, 210 species in 38 families of fish were assessed on various census transects. The ranges of numbers found on transects were 19–46 species/300 m^2 and 173–3,276 individuals/ 300 m^2. These parameters assessed in two different reef zones at each site are shown in Figures 2 and 3. Both species richness (SR; number of species per unit area) and abundance (number of individuals per unit area) of fishes were significantly greater on reef slopes than on reef flats (U-test, $P < 0.001$ for SR and $P < 0.01$ for abundance). The average SR and abundance of fishes for the reef slope transects were 35.9 ± 4.7 species/300 m^2 and 1,383 ± 712 individuals/300 m^2, respectively, while those for the reef flat were 27.7 ± 5.1 species/300 m^2 and 682 ± 440 individuals/300 m^2, respectively. Mean depth of the census belt-transect, which appears to be confounded with the effect of reef zones, was significantly correlated with the mean total abundance ($r = 0.70$, $P < 0.001$) and species richness ($r = 0.59$, $P < 0.005$).

Assemblage Patterns

The classification of fish assemblages among sampling sites/zones (stations) is illustrated by the dendrogram of percentage dissimilarity of Euclidean distances (Fig. 4). The analysis was based on abundance data of 169 selected species which occurred in at least two census stations. They represented about 98% of the total abundance per census station. The analysis showed a clear separation of fish assemblages between the reef-slope and reef-flat stations, with the exception of Station BF. The MDS configuration also showed discrimination between the two (Fig. 5). Furthermore, most of the reef-flat stations clustered tightly relative to those of the slope. It added little to the picture that the assemblages on reef flats were more homogeneous or had relatively little variability among sites compared to those of the slope sites. The grouping of Station BF in the slope cluster could be explained by the relative non-uniformity of this zone which represented by each replicate census. Two of the 5 transects at this station were set on the reef edge (outermost part of reef flat) where several typical slope-fish species had overlapping distributions. The slope-fishes found on the two transects included certain species of damselfishes, *Pomacentrus moluccensis*, *P. azuremaculatus* and *Chrysiptera rollandi*, the fusiliers *Pterocaesio chrysozona*, and the wrasse *Cirrhilabrus cyanopleura* (see later section).

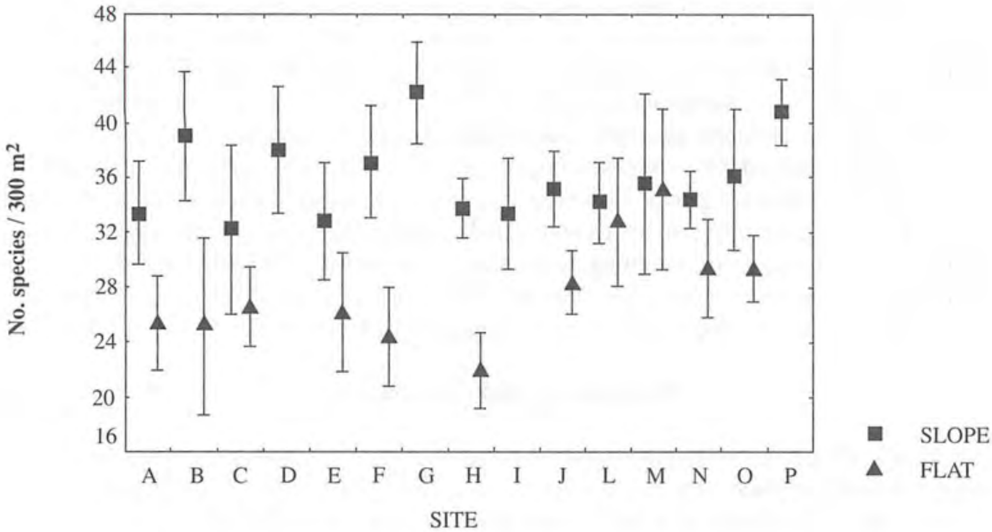

Figure 2. Number of fish species (mean ± SD) found in different reef zones (slope vs. flat) at each site.

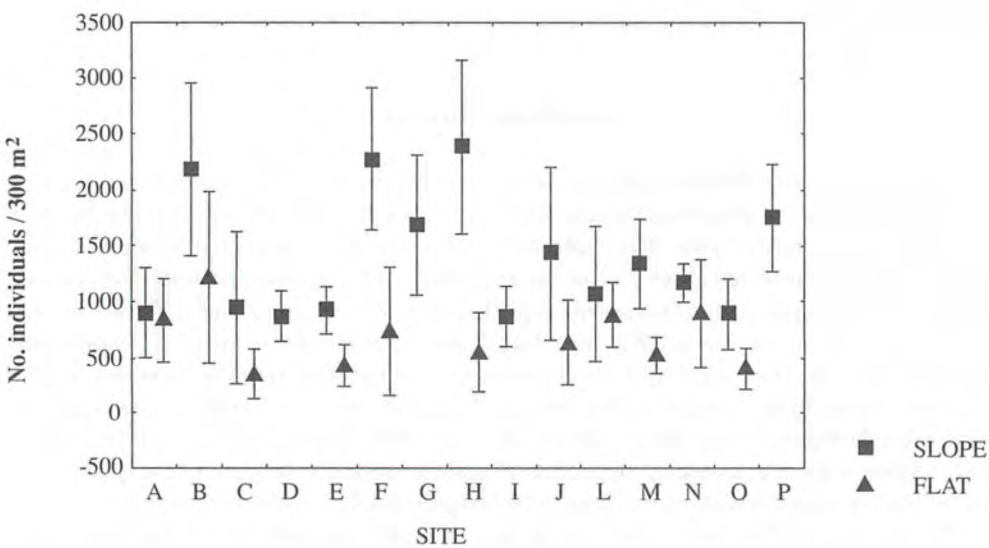

Figure 3. Abundance of fishes (mean ± SD) estimated in different reef zones (slope vs. flat) at each site.

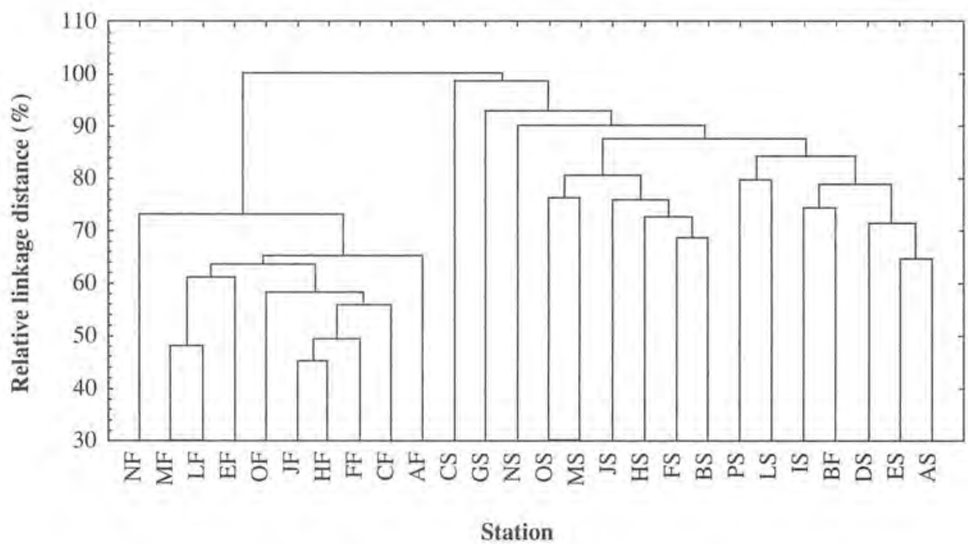

Figure 4. Dendrogram from dissimilarity matrix (Euclidean distance) of species abundance data among 26 census stations. The two-letters label for each station stands for the reef-site code (A–J; L–P) preceding the reef-zone code (F = reef flat; S = reef slope).

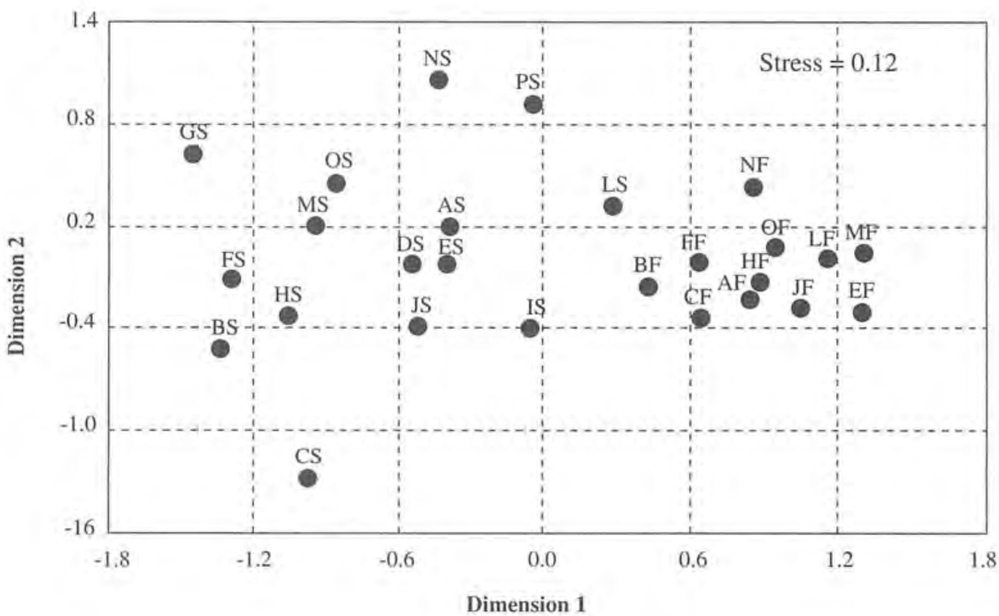

Figure 5. MDS ordination of the same dissimilarity matrix as for Figure 4. Station labels are the same as designated in Figure 4.

The abundance of the 60 most dominant species distributed among the whole stations is presented in Table 2. The distinct nature of the assemblages on reef flat and reef slope, as suggested by the cluster analysis, was also evident in a comparison of the distribution of several dominant species. Sixteen of the top 30 species were either exclusively dominant or relatively more common at the reef slope stations, while only 6 species were relatively dominant at the reef flat stations. The conspicuous or characteristic fish species found on the reef slopes included several damselfishes (*Chrysiptera rollandi, Pomacentrus azuremaculatus, P. moluccensis, P. pavo, P. amboiensis, Neopomacentrus cyanomos, N. filamentosus, Amblyglyphidodon leucogaster* and *Chromis cinerascens*), fusiliers (*Pterocaesio chrysozona* and *Caesio cuning*), cardinalfishes (*Apogon cyanosoma, Archamia fucata* and *Cheilodipterus quinquelineatus*), a wrasse (*Cirrhilabrus cyanopleura*), and a sweeper (*Pempheris vanicolensis*). On the reef flats, some characteristic fish included certain species of damselfishes (*Pomacentrus adelus, P. chrysurus* and *Plectroglyphidodon lacrymatus*), a sprat (*Spratelloides delicatulus*), a wrasse (*Halichoeres argus*), and a parrotfish (*Scarus quoyi*).

Figures 6 and 7 show distributions of the major trophic groups in the two reef zones. The significant differences, in terms of both species richness and abundance, were detected in all trophic groups except only for the invertebrate feeders. Again, the confounded effect of depth (mean depth of the belt-transect) with that of reef zone was reflected by the correlation between depth and each of parameters estimated for those trophic groups (Table 3). In all cases of significantly higher trophic parameters on the reef slope than on the reef flat (i.e. for the cases of omnivores, planktivores and piscivores), the correlations gave significantly positive coefficients. On the other hand, significantly negative correlations were shown when the trophic parameters (only for the cases of algal grazers) on the reef flat were sinificantly greater than on the reef slope.

Planktivores, omnivores and piscivores were significantly more abundant and diverse on the reef slope than on the reef flat. The higher abundance of planktivorous species on the reef slope (Table 4) was contributed largely by members of Pomacentridae (*Amblyglyphidodon leucogaster, Neopomacentrus cyanomos, N. filamentosus, Chromis cinerascens, C. weberi* and *C. ternatensis*), Caesionidae (*Pterocaesio chysozona* and *Caesio cuning*), Apogonidae (*Apogon cyanosoma, A. compressus* and *Archamia fucata*), Pempheridae (*Pempheris vanicolensis*) and Labridae (*Cirrhilabrus cyanopleura*). Most of these were either scarcely present or absent on the reef flat. *Neopomacentrus azysron* was among the most dominant planktivores but equally abundant in both reef zones (Table 2).

Damselfishes (Pomacentridae) were the primary omnivorous fishes that exhibited different distribution patterns in the two reef zones. The significant peaks in abundance of *Pomacentrus moluccensis, P. azuremaculatus, P. amboinensis, P. pavo* and *Chrysiptera rollandi* on the reef slope accounted for the relatively high abundance of omnivores in this zone (Tables 2 & 4). Four species of omnivorous damselfishes had abundance peaks on the reef flat (*Pomacentrus adelus, P. chrysurus, Plectroglyphidodon lacrymatus* and *Stegastes obreptus*).

A few piscivores were significantly higher in both species richness and abundance on the reef slope than on the reef flat: *Cheilodipterus macrodon, Anyperodon leucogrammicus* and *Synodus variegatus*). Most piscivorous species, particularly members of Serranidae (groupers), had uneven distribution among reef sites and/or were not numerically abundant in the census area. Hence, not many species were properly tested statistically.

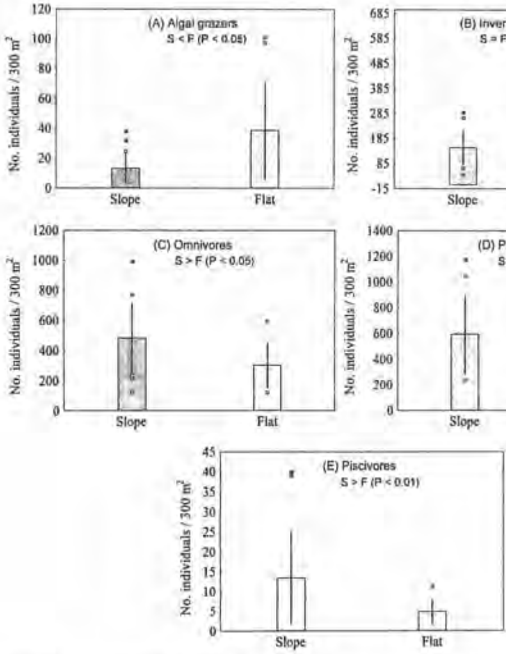

Figure 6. Species richness (mean ± SD, with outlier (circle) and extreme (star) values) of 5 trophic groups of fishes in two zones of the reefs of Adang-Rawi Islands together with the result of U-test comparing the difference between zones (F = reef flat, S = reef slope).

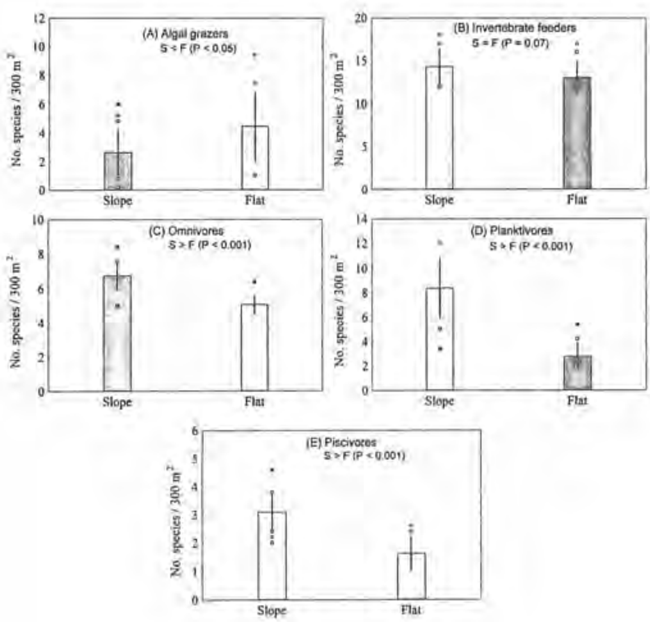

Figure 7. Abundance (mean ± SD, with outlier (circle) and extreme (star) values) of 5 trophic groups of fishes in two zones of the reefs of Adang-Rawi Islands together with the result of U-test comparing the difference between zones (F = reef flat, S = reef slope).

Table 2. Sorting list of mean abundance (based on mid-point of abundance categories) of the 60 most dominant species contributed to each census station. Underlining at mean value denotes significantly greater abundance of the species in particular reef zone (U-test: *P < 0.05; **P < 0.01; ***P < 0.001).

Species	Family	Reef slope station															AVG.	Reef flat station											AVG.
		AS	BS	CS	DS	ES	FS	GS	HS	IS	JS	LS	MS	NS	OS	PS		AF	BF	CF	EF	FF	HF	JF	LF	MF	NF	OF	
Pomacentrus moluccensis	Pomacentridae	232	18	0	88	64	40	160	56	82	112	256	136	208	96	136	112.3*	15	298	11	0	45	28	14	48	64	40	28	53.6
Pomacentrus adelus	Pomacentridae	22	3.2	1.4	34	40	14	88	34	40	40	112	40	28	24	34	37.0	136	88	88	82	352	136	112	208	160	160	112	148.5***
Neopomacentrus azysron	Pomacentridae	8	0	0	82	48	18	112	224	96	64	208	352	8	40	0	84.0	48	72	58	40	208	232	56	24	8	12	32	71.8
Chrysiptera rollandi	Pomacentridae	34	232	48	64	88	352	160	160	40	112	112	136	136	112	28	120.9***	0	2.6	0	0	1.2	0	0	0.2	0	0	0	0.4
Pterocaesio chrysozona	Caesionidae	82	448	168	4	16	136	192	256	64	397	0	0	0	0	0	117.5*	0	34	8	0	0	0	0	0	0	0	0	3.8
Spratelloides delicatulus	Clupeidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	416	448	0	32	0	0	0	424	40	442	0	163.8*
Pomacentrus azuremaculatus	Pomacentridae	88	352	17	2.6	88	544	88	256	8.2	58	4.6	88	19	112	8	115.5***	0	0.6	0	0	0	0	0	0	0	0	0	0.1
Apogon cyanosoma	Apogonidae	0	232	66	42	112	130	144	448	48	232	0	18	0	48	0	101.3**	16	0	4	0	0	0	0	0	0	0	0	1.8
Amblyglyphidodon leucogaster	Pomacentridae	52	3.8	0	0.6	6.6	19	6	4.6	24	10	8	0.6	112	56	621	61.6**	6	10	0	0	0	0	0	0	0	26	3.8	4.2
Archamia fucata	Apogonidae	0	192	32	0	0	232	136	40	0	40	0	128	40	32	0	58.1**	0	0	0	0	0	0	0	0	0	0	0	0.0
Cheilodipterus quinquelineatus	Apogonidae	8	58	8	2	80	88	34	232	0	74	8	42	56	104	4	53.2**	10	0	8	0	10	0	0	0	0	12	0	3.6
Pomacentrus amboiensis	Pomacentridae	4.6	80	28	6	0.6	11	56	2	2	28	12	20	13	18	544	55.0***	0	0	0	0	0	0	0	0	0	0	0	0.0
Thalassoma lunare	Labridae	8.6	34	28	40	34	34	40	64	34	40	22	16	22	8	40	31.0	5.8	58	7.2	16	13	40	64	34	28	22	8.6	27.0
Pomacentrus pavo	Pomacentridae	76	2	15	32	88	20	16	48	4	10	104	34	160	26	4	42.6**	17	8	2.6	2	3.2	0	0	2	0	45	2.6	7.4
Abudefduf vaigiensis	Pomacentridae	16	0	0	0	0	0	8	34	104	40	0.6	0	32	0	9.4	16.3	11	73	0.6	0	2	34	208	3.8	8.6	0	24	33.1
Pempheris vanicolensis	Pempheridae	32	2	0	50	134	26	0	98	42	0	66	40	0	33	13	35.7*	2	8	2	0.6	0	0.8	2	0	0	0	32	4.3
Lutjanus lutjanus	Lutjanidae	0	138	0	0	0	32	0	256	138	0	0	0	0	0	0	37.6	0	0	0	0	0	0	0	0	0	0	0	0.0
Halichoeres vrolikii	Labridae	7.2	16	40	32	10	26	34	22	34	34	7.2	7.2	6.6	3.2	8.6	19.2	6.6	21	13	8.6	28	22	28	4.6	16	8.6	7.2	14.8
Neopomacentrus cyanomos	Pomacentridae	0	200	0	16	0	8	0	32	0	0	0	44	16	8	0	21.6*	0	0	0	0	0	0	0	0	0	0	0	0.0
Neopomacentrus filamentosus	Pomacentridae	18	0	8	2	20	160	10	8	2	0	0	16	56	8	0	20.5**	0	0	0	0	0	0	0	0	0	0	0	0.0
Neopomacentrus anabatoides	Pomacentridae	16	0	0	40	0	200	0	0	0	8	2	0	0	2	0	17.9	8	8	0	0	2	0	0	0	0	0	8	2.4
Cirrhilabrus cyanopleura	Labridae	16	10	14	11	0.6	50	42	10	10	32	0	58	0	18	10	18.7***	0	8	0	0	0	0	0	0	0	0	0	0.7
Amphiprion ocellaris	Pomacentridae	3.2	6.6	4	34	19	7.2	22	8	0.6	16	1.2	12	34	6.6	14	12.5	0.6	11	0.6	11	2.6	2.6	1.2	4	15	22	2	6.6
Caesio cuning	Caesionidae	8	48	48	48	12	16	16	0	0	0	0	8	0	8	2.8	14.3*	0	8	32	0	0	0	0	0	0	0	0	3.6
Chromis cinerascens	Pomacentridae	2.6	13	48	88	0	26	24	0	0	10	0	18	0	0	2	15.4*	0	0	0	0	0	0	0	0	0	0	0	0.0
Halichoeres argus	Labridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	82	2	28	51	8.6	7.2	10	16	8.6	0.6	5.2	19.9***
Scarus quoyi	Scaridae	0.8	1.4	1.2	3.2	0	4.6	2.8	0	0.6	4.2	15	6.6	0.8	1.8	5.8	3.2	7.2	0	7.2	15	15	0	16	11	27	13	2.4	10.2*
Plectroglyphidodon lacrymatus	Pomacentridae	3.2	0	0	1.2	2	0	12	0	2.6	4	0	0	0	0	0	1.7	0	4	1.8	8	12	6.6	11	2.6	3.8	5.8	52	9.7*
Caesio caerulaurea	Caesionidae	48	0	0	8	8	0	24	0	0	0	0	32	0	0	0	8.0	0	0	4	0	0	0	0	0	0	0	0	0.4
Pomacentrus chrysurus	Pomacentridae	0	0	0	2.6	0	0	0	0	2	0	0	0	0	0	0	0.3	3.2	0	13	27	0	3.2	22	13	16	0	19	10.5**

Species	Family	Reef slope station															AVG.	Reef flat station											AVG.
		AS	BS	CS	DS	ES	FS	GS	HS	IS	JS	LS	MS	NS	OS	PS		AF	BF	CF	EF	FF	HF	JF	LF	MF	NF	OF	
Amphiprion akallopisos	Pomacentridae	0.6	0.6	2	4.6	2.6	2	26	1.2	0.6	1.2	0.6	16	10	5.2	2.6	5.1	0	0.6	0	2.6	0.6	2.6	2.6	1.2	4.4	22	0	3.3
Chromis weberi	Pomacentridae	2.6	0	11	44	0	0	42	0.6	0	2.6	0	0	0	2	0	7.0*	0	0	0	0	0	0	0	0	0	0	0	0.0
Apogon compressus	Apogonidae	0	4	0.6	0	2	8	0	16	0	0	0	8	40	0	10	5.9**	0	0	0	0	0	0	0	0	0	0	0	0.0
Scolopsis bilineatus	Nemipteridae	1.4	7.2	7.2	3.8	2.6	2.4	3.8	3.2	4.4	6.6	5.8	3.4	2	1	4.4	3.9	0.2	0.6	2.6	3.2	1.8	3	7.2	4.8	0	2.6	0.6	2.4
Chromis ternatensis	Pomacentridae	2.6	12.6	0	0	0	0	2	2	8	0	0	6.6	27	26	18	7.0*	0	0	0	0	0	0	0	0	0	8	0	0.7
Zanclus cornutus	Zanclidae	1.8	3	1.2	8.6	4	6.6	10	1.8	5.8	5.8	2	2.6	4.6	0.8	5.8	4.3**	0.8	1.4	0.4	1.2	1.6	0.8	11	0.8	0.6	0.6	0.2	1.7
Chaetodon triangulum	Chaetodontidae	4.4	1.2	0.8	1.2	1.8	2	3.8	1.4	5.8	2.6	7.2	2.6	4.4	2	7.2	3.2	1	4	1.2	0.8	2.2	1.4	3	5.8	7.2	4	3	3.1
Stegastes nigricans	Pomacentridae	0.8	0.2	0	0	10	0.8	0.6	2	0	0.6	3.8	0	7.2	2	12	2.7	0.4	1.8	0.2	20	1.6	0	0	2.4	2	8.6	0.6	3.4
Cephalopholis polyspila	Serranidae	2	2.2	0.8	5.8	1	3.8	4.4	4	1.8	2.6	2	7.2	1.8	6.4	2.6	3.2	0.8	5	1.6	4	1.4	0.8	2	1	0.6	3.4	5	2.3
Halichoeres hortulanus	Labridae	4.4	0.4	1.2	1.8	1.2	0.6	3.8	4.4	6.6	5.2	1	0.8	4.6	3.8	0.8	2.7	3.4	1.8	2.6	2.2	2.6	3.8	2.4	2.6	3.8	0	4	2.7
Chaetodon octofasciatus	Chaetodontidae	10	5.8	0	5.2	2.6	4.6	5.8	3.4	7.2	0	5.2	0	5.2	1.2	4	4.0**	0.2	1.8	0	0	1.2	0	0	0	0	4.4	0	0.7
Lutjanus decussatus	Lutjanidae	0.2	1.4	0.6	1.2	0.2	1.2	1.4	0.6	0.6	3.4	8.6	3.4	0	0.8	0.6	1.6	1.2	1.2	3.6	7.2	2.6	1	8.6	8.6	5.8	2.2	1.2	3.9*
Chlorurus sordidus	Scaridae	0	0	0	0.2	0	1.8	0	0	0	1.8	7.2	2	4	0	2.2	1.3	1	0.8	3.2	3.2	2.6	0	5.2	11	14	2.6	4.6	4.3**
Halichoeres marginatus	Labridae	2	1	0.6	1.2	1.6	1.4	2.2	1.2	5.8	3.2	0.4	0.6	2.6	1.2	1.8	1.8	3.6	1.4	4.4	3.4	2.4	4.4	7.2	5.2	3	0.2	3.8	3.5*
Chrysiptera unimaculata	Pomacentridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	2	0	2.6	42	0	0.6	0	4	2	0	11	5.8**
Siganus canaliculatus	Siganidae	0	2.6	2.8	2.6	0	0	0.6	0	0	0	0.6	0	0	1.2	2.2	0.8	0.2	0	0	0	0	0	0	3.4	32	0.2	8.2	4.0
Scarus niger	Scaridae	0	0	0	0.6	0	0	4.6	0	1.8	0.6	0.6	0.2	4.4	3.8	5.2	1.5	0	0.6	0.2	1.2	1.2	0.8	5.2	3	8.6	0.2	2.4	2.1
Dischistodus perspicillatus	Pomacentridae	0	0	3	0.4	0	0	0	0	0.6	0	0.8	0	0	0	0	0.3	16	0	4.2	13	0.2	0	0.2	2.4	0.2	0.6	1.2	3.4*
Stegastes obreptus	Pomacentridae	0	0	0	0	0	0	0	0	2.2	0	0	0	0	0	0	0.1	1.8	0	3.4	1.8	2	7.2	21	0	0.6	0	0	3.4*
Labroides dimidiatus	Labridae	0	1.8	0	1.2	1.6	1.2	3.8	2.4	1	0.6	1.2	2	0	1.8	4.6	1.5	0.4	0	2	0.2	1.6	1.8	3.4	0.2	4	0.2	2.2	1.5
Scolopsis lineatus	Nemipteridae	0	0	0	0	0	0	0	0	0	0	2.6	0.8	0	0	0.6	0.3	0	4.6	2.6	2.8	0	1.6	2.4	7.2	8.6	3.4	0.8	3.1**
Cheilodipterus macrodon	Apogonidae	1.4	2	0	0	0.8	10	0	5.2	0.2	2	0.6	0	0	10	0	2.1*	0	0.6	0	0	0	0	0	0	0	0	0	0.1
Parapercis hexophthalma	Pinguipedidae	1.4	1.4	5.8	2.8	1.4	1	1.2	0.6	1.8	3	1.4	0	0	2.8	0.6	1.7*	2	0.8	1.2	1	0	0	0	1.2	0.2	0	0	0.6
Synodus variegatus	Synodontidae	1.2	6.8	4.4	3	3.4	2	0	0.6	1.2	2.4	1	0	1.2	0.6	0	1.9*	0	0.6	1.4	0.6	0	0.2	0.2	0	0	0.8	0	0.3
Coris batuensis	Labridae	2	2.6	3.8	1.2	1	0.2	1.8	0.2	4	3.8	2.8	0	0.6	1	0.6	1.7***	1.2	0.6	0.2	0	0	0	0	0	0	0	0	0.2
Neoglyphidodon nigroris	Pomacentridae	3.2	0	0	1	1.2	5.2	5.2	1.2	0	0	0.2	0.2	0	0	0	1.2	0	1.2	0	2	1.4	0	0	0	0	1.2	3.2	0.8
Lutjanus biguttatus	Lutjanidae	0	3.4	0.6	3.4	0	0	0	0.6	8.6	2.6	0	3.4	0.6	4.6	0.6	1.9*	0	4	0	0	0	0	0.	0	0	0	0	0.4
Halichoeres scapularis	Labridae	0	0	2.6	0.4	2	0	0	0	0.2	0.6	3.8	0	0	1.2	0.8	0.8	0.8	0.6	2	0.6	0.6	0.2	1.2	1.8	2.6	0	2	1.1
Epibulus insidiator	Labridae	1	3	0	0.8	0.6	0.8	1.2	2.8	0.6	0.6	0.2	0	0.8	0	2	1.0	0.6	1.4	0	0.2	0.6	1.2	1.2	0	1.8	1.8	0.8	0.9
Labrichthys unilineatus	Labridae	0	0	0	1.4	2.2	1.4	1.8	1.2	0.8	0	0.6	2	1.4	1	2.4	1.1	0.4	0	0	0	0.4	0	0.2	0	2.6	1.4	0.8	0.5

Table 3. Correlations (Spearman's Rank) between mean depth of the census belt-transect and the parameters estimated for each trophic group of fishes. Significance levels are given at *P < 0.05, **P < 0.01, and ***P < 0.001.

Parameters: Trophic groups	r
Species richness:	
Algal grazers	– 0.504**
Invertebrate feeders	+ 0.130
Omnivores	+ 0.526**
Planktivores	+ 0.812***
Piscivores	+ 0.682***
Total abundance:	
Algal grazers	– 0.491*
Invertebrate feeders	+ 0.285
Omnivores	+ 0.420*
Planktivores	+ 0.442*
Piscivores	+ 0.537**

Invertebrate feeders, being generally the most diverse trophic group on coral reefs, were relatively common in both reef zones but different sets of species characterized each zone. The invertebrate feeders abundant on the reef slope comprised members of Apogonidae (*Cheilodipterus quinquelineatus*), Chaetodontidae (*Chaetodon octofasciatus*), Labridae (*Bodianus neilli, Cheilinus fasciatus* and *Coris batuensis*), Pinguipedidae (*Parapercis hexopthalma*), Lutjanidae (*Lutjanus lutjanus*) and Zanclidae (*Zanclus cornutus*). On the reef flat, only a few families had significantly greater abundance: Labridae (*Halichoeres argus, H. chloropterus, H. marginatus* and *Stethojulis trilineata*); Lutjanidae (*Lutjanus decussatus*); and Nemipteridae (*Scolopsis lineatus*).

Several algal grazers had significantly higher abundance on the reef flat than on the reef slope (Figs. 6 & 7). These included members of Scaridae (*Scarus quoyi* and *Chlorurus sordidus*), Pomacentridae (*Chrysiptera unimaculata* and *Dischistodus perspicillatus*) and Siganidae (*Siganus guttatus*).

Fish Diversity and Reef features

To exemplify the underlying relationship between fish and coral reef, the simplest available parameters of both fish (diversity) and coral reef (geomorphological features) were used for regression analysis. Species richness was here adopted as a simple measure of fish diversity. For each reef site, the number of fish species encountered in either reef zone (including additional species recorded outside the census belt-transects) were pooled together and represented the total fish diversity of the site. Geomorphological features of each reef site included depth [maximum depth (m) of the reef border], perimeter [total length (km) of the reef estimated from the outline of the border of reef slope], and area [integrated extent (km^2) of reef system estimated from the reef border onto the shoreline

Table 4. Trophic grouping of selected species that show greater representation in abundances in particular reef zone (U-test: *P < 0.05, **P < 0.01, ***P < 0.001). Trophic groups include algal feeders (Ag); benthic-invertebrate feeder (If); omnivore (Om); planktivore (Pk); and piscivore (Ps). + denotes reef slope > reef flat; – denotes reef flat > reef slope.

Species	Family	Ag	If	Om	Pk	Ps	P level
Apogon compressus	Apogonidae				+		**
Apogon cyanosoma	Apogonidae				+		**
Archamia fucata	Apogonidae				+		**
Cheilodipterus macrodon	Apogonidae					+	*
Cheilodipterus quinquelineatus	Apogonidae		+				**
Caesio cuning	Caesionidae				+		*
Pterocaesio chrysozona	Caesionidae				+		*
Chaetodon octofasciatus	Chaetodontidae		+				**
Spratelloides delicatulus	Clupeidae				–		*
Cirrhilabrus cyanopleura	Labridae				+		***
Bodianus neilli	Labridae		+				**
Cheilinus fasciatus	Labridae		+				*
Coris batuensis	Labridae		+				***
Halichoeres argus	Labridae		–				***
Halichoeres chloropterus	Labridae		–				*
Halichoeres marginatus	Labridae		–				*
Stethojulis trilineata	Labridae		–				**
Lutjanus decussatus	Lutjanidae		–				*
Lutjanus biguttatus	Lutjanidae		+				*
Scolopsis lineatus	Nemipteridae		–				**
Pempheris vanicolensis	Pempheridae				+		*
Parapercis hexophthalma	Pinguipedidae		+				*
Amblyglyphidodon leucogaster	Pomacentridae				+		**
Chromis cinerascens	Pomacentridae				+		**
Chromis ternatensis	Pomacentridae				+		*
Chromis weberi	Pomacentridae				+		*
Chrysiptera rollandi	Pomacentridae			+			***
Chrysiptera unimaculata	Pomacentridae	–					**
Dascyllus trimaclatus	Pomacentridae				+		*
Dischistodus perspicillatus	Pomacentridae	–					*
Neopomacentrus cyanomos	Pomacentridae				+		*
Neopomacentrus filamentosus	Pomacentridae				+		**
Plectroglyphidodon lacrymatus	Pomacentridae			–			**
Pomacentrus adelus	Pomacentridae			–			***
Pomacentrus amboiensis	Pomacentridae			+			***
Pomacentrus azuremaculatus	Pomacentridae			+			***
Pomacentrus chrysurus	Pomacentridae			–			**
Pomacentrus moluccensis	Pomacentridae			+			*
Pomacentrus pavo	Pomacentridae			+			**
Pomacentrus philippinus	Pomacentridae			+			*
Stegastes obreptus	Pomacentridae			–			*
Chlorurus sordidus	Scaridae	–					**
Scarus quoyi	Scaridae	–					*
Anyperodon leucogrammicus	Serranidae					+	**
Siganus guttatus	Siganidae	–					*
Synodus variegatus	Synodontidae					+	*
Zanclus cornutus	Zanclidae		+				**
Total	+ =	0	8	6	14	3	
	– =	5	6	4	1	0	

continuously along the full length of each reef site]. The latter two features were derived from the coral reef maps of the island group established by Phongsuwan (1999). Among these geomorphological features, significant correlation was detected only between reef perimeter and area (Pearson's $r = 0.70$, $P < 0.01$). The relationships between fish diversity and each reef geomorphological feature are shown in Figure 8. Fish diversity increased significantly with increasing perimeter and area of the reefs, but not with depth. Perimeter and area explained 37% and 31%, respectively, of the variation in the number of fish species on coral reef.

DISCUSSION

Zonation of Fish Assemblages

The present study clearly shows that the distinct assemblages of fishes are associated with different zones on the reef. Patterns of zonation of reef fishes have also been documented elsewhere (e.g. ALEVIZON *ET AL.*, 1985; RUSS, 1989; COLES & TARR, 1990; MEEKAN *ET AL.*, 1995; GREEN, 1996; LETOURNEUR, 1996; CHABANET *ET AL.*, 1997), while this study represents the first detailed description, particularly based on quantitative data, of such zonation in Thai waters. There is also good evidence to suggest that patterns of zonation can be maintained through time, despite temporal variation in the density of individual species associated with different habitat zones (e.g. RUSS, 1984b; GREEN, 1996; LETOURNEUR, 1996). Among the investigated sites, reef slope stations had greater total fish abundances and species richness than the reef flat stations. The results of the clustering procedures strongly support the view that the two reef zones are utilized as different habitats by fishes. Many fish species are exclusively confined to, or achieve their greatest abundances on, the reef slope, whereas a smaller number of species show greater abundance on the reef flat. In general, fishes are strongly dependent on coral reefs as for food sources, shelter or resting sites. The organization of fish communities may be closely related to substrate structure (ROBERTS & ORMOND, 1987; MCCORMIC, 1994; CHABANET *ET AL.*, 1997). No rigorous measurements of reef substrate were made in the present study. However, my own observation at the sites and the preliminary data gathered by the team scientists in the same sampling program (PHONGSUWAN *ET AL.*, 2001) suggest that there were substantial differences in coral communities among sites and obviously between the two reef zones. Almost all reef slope sites have greater coverage of live corals as well as a greater number of coral species. The reef flat is characterized and dominated by the massive *Porites lutea* (mainly as micro-atoll forms), small heads of other massive corals (i.e. *Favia*, *Favites* and *Goniastrea*), and short-branched or digitate growth-form corals (i.e. *Montipora digitata* and certain species of *Acropora*). The reef slope sites are dominated by large-sized massive *P. lutea*, *Lobophyllia* sp., and long branched growth-forms of *Acropora* (i.e. *A. formosa* and *A. florida*). The assemblage of large *P. lutea* colonies usually provides complex habitat structures with crevices and holes and also provides a specific habitat of shaded area underneath the coral colonies. The spaces and bottom topography formed by the assemblage of long branched *Acropora* are inevitably complex. The type of substrate, notably coral species composition, living coral coverage and growth-form, and their characteristic (or structural complexity) seem to vary greatly between reef zones in

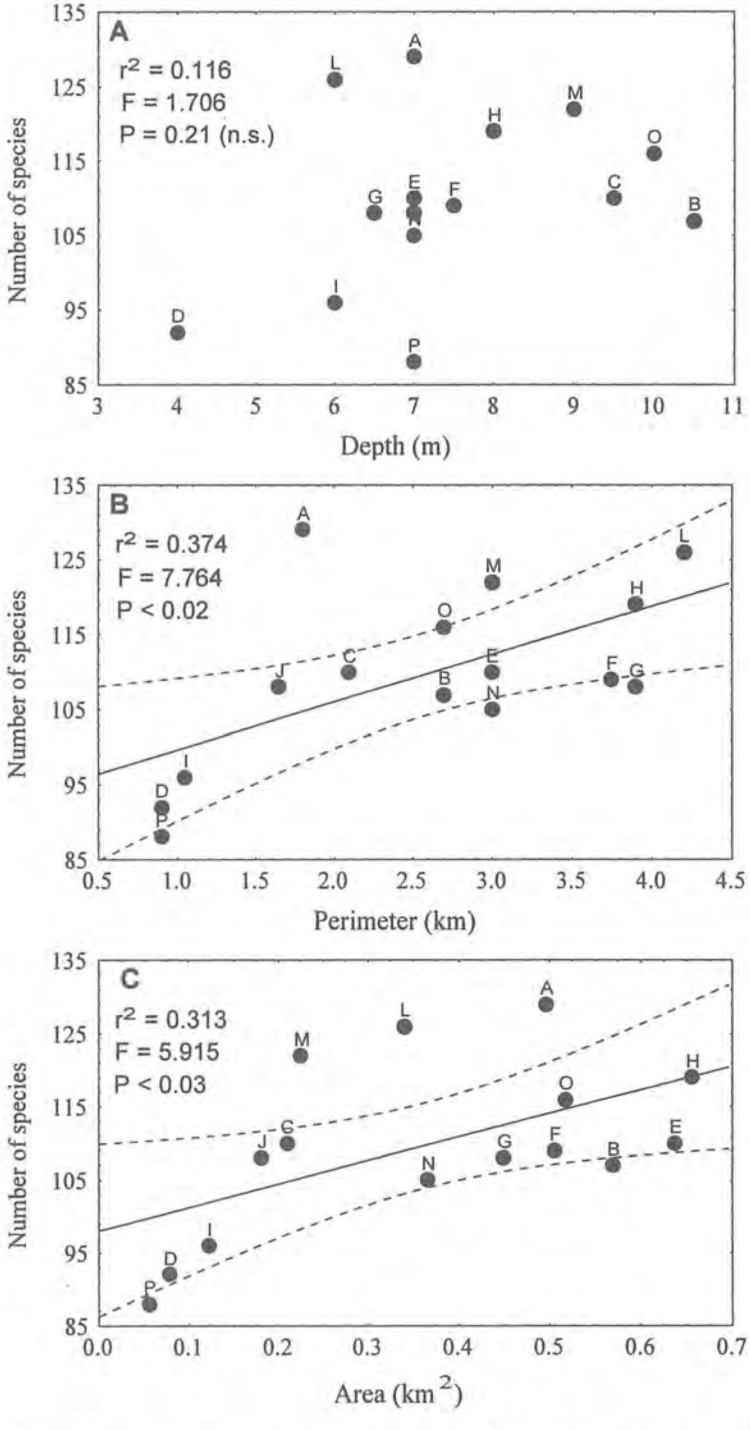

Figure 8. Relationships between species diversity of fishes and geomorphological features of coral reefs, including (A) depth, (B) perimeter, and (C) reef area. Label at the data point indicates the site code.

accordance with the influence of different environmental conditions. The stressful hydrodynamic conditions regarding tidal regime and wave action on reef flats may regulate the coral community and hence limit the composition of occupant fishes exclusively to those that have acquired the necessary adaptive responses. In contrast to the reef flat, the more uniform and less stressful conditions in the slope zone may provide opportunity for a greater variety of corals and fishes. Such a situation may also promote spatial variation among the slope-fish assemblages, as suggested by the heterogeneity of the slope-site clusters compared to that of the reef flat (Fig. 5). In this regard, to determine such relationships, further combined analysis between fish and coral (substrate) variables is required. The substrate variables and their topographical complexities have been either claimed (e.g. RUSS, 1989; COLES & TARR, 1990; SHEPHERD *ET AL.*, 1992) or elucidated (e.g. CARPENTER *ET AL.*, 1981; BELL & GALZIN, 1984; ROBERTS & ORMOND, 1987; MCCORMICK, 1994; CHABANET *ET AL.*, 1997; TOLIMIERI, 1998) as the prime factors influencing either abundance of particular fish populations or the overall assemblage of fishes.

The zonation pattern is also pronounced with respect to the trophic groups of fishes in each zone. Planktivorous fishes are one of the most diverse groups on reef slope and appear to contribute the greatest proportion of the total abundance of fishes in this zone. This zone is the foremost part of the reef that has direct connection to the sea, irrespective of the stage of tides. In contrast to the reef slope, several reef flat stations are partially exposed during low spring tides. The availability of planktonic prey and the uniformity of conditions in the water column are likely to explain the well established assemblage of planktivores in the slope zone. THRESHER (1983) found that the abundance of planktivorous fishes was positively correlated with current strength and reef depth. In contrast to the reef flat, this reef zone also contains more representatives of the other trophic groups, omnivores and piscivores. Damselfishes (Pomacentridae) are the most abundant omnivores. They are mainly site-attached and territorial species which tend to selectively adapt to or largely use bottom structures for refuges, nesting sites and food sources. A study in the Red Sea by ROBERTS & ORMOND (1987) found positive correlations between structural complexity of substratum (surface index) and pomacentrid abundance and species richness. Similarly for the studies in the northern Great Barrier Reef, Australia; MCCORMICK (1994) found that the patterns of pomacentrid assemblages were strongly influenced by depth and bottom topography, and MEEKAN *ET AL.* (1995) demonstrated distinct differences in pomacentrid assemblages among reef zones. In the present study, the differences in distribution and abundance of species in omnivorous trophic groups between the two reef zones may depend largely on differences in bottom structures between zones. Piscivores are strongly dependent on small fish prey. A vast variety and of abundant of small-sized fishes typically hover or aggregate close to the bottom structures on the reef slope. The abundance of small fishes as prey may explain the relatively high abundance and diversity of piscivores in this reef zone.

On the reef flat, algal grazers are the most characteristic group. RUSS (1984a) suggested a causal relationship between the availability of algae as food and the abundance of herbivorous fishes. Extensive dead coral surfaces overgrown by filamentous algae are peculiar to this zone. Abundant algal food in this zone could attract the assemblage of herbivorous damselfishes, parrotfishes and rabbitfishes, although there is circumstantial evidence that the latter two groups seem to form temporary assemblages through their diurnal feeding aggregation during high tides (personal observations).

Invertebrate feeders are the most diverse trophic group in both reef zones. The vast variety and abundance of reef-associated benthic invertebrates explain the high diversity of this carnivorous group on coral reefs (SUTTON, 1983). Although the figures of mean species richness (Fig. 6a) and total abundance (Fig. 7a) do not show a strong zonal pattern, the differences in composition of species that have peak abundances in each zone suggest differences in the assemblages of invertebrate feeders between the two reef zones.

The results of this study conform to other studies in various aspects of the trophic structure of reef fishes, for which certain generalizations can be drawn, such as: 1) the highest diversity of fishes on coral reefs is manifested by invertebrate feeders compared to the other trophic groups (SUTTON, 1983; WILLIAMS & HATCHER, 1983; SATAPOOMIN & CHANSANG, in press); 2) the greatest dominance of planktivores (as well as the relatively high abundances of omnivores and piscivores) is on the reef slope (WILLIAMS & HATCHER, 1983; RUSS 1989; MEEKAN *ET AL.*, 1995; SATAPOOMIN & CHANSANG, in press); and 3) a particularly high abundance of algal grazers occurs in the shallow water zones (e.g. reef flat, reef edge and lagoons) of the reefs (RUSS, 1984a, 1984b, 1989; MEEKAN *ET AL.*, 1995). These observations provide further indication that each reef zone functions differently in supporting a range of ecological niches of fishes.

There were small but significant positive relationships between fish diversity and reef perimeter ($r^2 = 0.37$, $F = 7.76$, $P < 0.02$) and reef area ($r^2 = 0.31$, $F = 5.92$, $P < 0.03$). The pattern conforms to that found by Galzin *et al.* (1994) who obtained positive correlations between size (perimeter) of the lagoon and fish diversity in French Polynesia, and also suggested a conformity to predictions of MacArthur & Wilson's theory of island biogeography. The perimeter and area as defined in this study also relate the degree of development of each reef site. The larger the size and area the more development and complexity of the reef system which, in turn, supports higher fish diversity. However, the small coefficient of determination (r^2) value found in the present analysis may suggest that geomorphological features alone are not the best predictors of fish communities. Various taxomonic groups of reef-associated fishes with different ecological niches may be affected more by several other ecological factors or processes (e.g. living coral cover, food diversity and availability, competitive interactions, predation, and recruitment) than geomorphological features of the reef system. Nonetheless, these features are easy to estimate and are potentially useful, together with other features, in identifying core areas for coral reef reserves.

Management Implications

Trap fishing is a common practice and is widespread in nearly all reef sites in this island group. Traps are usually placed on the lower part of the reef slope and may extend into the fore-reef zone of the sandy area with scattered coral outcrops. Because no attempts have been made to evaluate catches and fishing intensity in the area, and there are no unfished reef sites, it is not possible to make a reasonable assessment of the impact of trap fishing on fish communities. From general observations, the fishes usually found in the traps include snappers (*Lutjanus*), fusiliers (*Caesio*), emperrors (*Lethrinus*), groupers (*Epinephelus* and *Plectropomus*), trevallys (*Caranx* and *Carangoides*), rabbitfishes (*Siganus*), surgeonfishes (*Acanthurus*), butterflyfishes (*Chaetodon* and *Heniochus*), angelfishes (*Pomacanthus*), porcupinefishes (*Diodon*) and puffers (*Arothron*).

According to the Marine Park Act, no resources within a park area may be harmed, hunted, or harvested. Strictly speaking, any kind of fishing practice in the park is considered illegal. However, fishing activities of local inhabitants (sea-gypsies) around this island group have never been enforced. It would be sensible to legally give fishing permits to local fishermen on the ground that they are strongly dependent on reef resources and should have rights to fish for daily consumption. But what happens today is the development of commercial fishing communes for which local fishermen are employed to fish for a few investors. Various types of fishing have been employed, such as trapping, trolling, and hand-line fishing. The major proportion of the catch is directly exported to Lankawi Islands, Malaysia. Consequently, fishing intensity in the area is no longer at a low and sustainable level. It is not my attempt to say whether such a fishing system is right or wrong. In the present situation, it appears that a complete ban on fishing is not a workable solution, as it will bring about hardship or political conflict. In this regard, the responsible authorities should take into account the coexistence of fisheries and sustenance of fish resources in the park area. At the same time, the area is becoming a popular destination for tourists with an increase in related recreational activities, particularly those that use coral reefs in the park. In this regard, the establishment of effective management, particularly multiple use management, for coral reef areas is urgently needed. The essence of multiple use management is providing for conservation and reasonable consumptive use (KENCHINGTON, 1988). Fishing area should not be completely widespread, but should be restricted to certain defined sites. At the same time, reserved or protected areas must be established as well. It is widely recognized that marine protected areas that exclude fishing provide a refuge for fish populations, give a chance for brood stocks to reproduce, and either sustain or increase fish diversity, abundance, and biomass (e.g. RUSS *ET AL.*, 1992; ROBERTS & POLUNIN, 1993; RUSS & ALCALA, 1994; WANTIEZ *ET AL.*, 1997; CHIAPPONE *ET AL.*, 2000; MCCLANAHAN & ARTHUR, 2001).

The size, number, and placement of the reserved areas are matters for further consideration. While there has been less consensus on the appropriate size for either coral reef reserves or marine parks in general, there is an increasing concern about the failure of parks which have been formally created but are not managed (so-called "paper parks"), irrespective of how large they are. If any specific sites in this island group are to be established as reserved areas, careful consideration should be placed upon the following aspects: a) the areas should be of appropriate size but not too large, until management, surveillance, and enforcement are practically possible; b) the areas should represent both outstanding biological resources and significant ecological functions so that they can contribute to the maintenance of resources of the surrounding ecosystems; and c) for implementation, the areas have to be committed to and co-managed by the relevant stakeholders, include Marine Park and Fisheries Department personnel, investors, fishers, and other resource users. It is beyond the scope of this paper to cover more details for the above three aspects. However, the findings of the present study may provide a cue for selection of the suitable reserved sites. Conventionally, planners or policy makers usually prioritize the areas which are particularly diverse and productive to be selected as sites for the reserves. In this context, certain ecological criteria must be used, for instance, biological diversity (including corals, fishes and others reef-associated organisms), reef condition and development, and biological production. The strong relationships between fish communities and substrate characteristics (living coral covers and their growth-form components) and between fish diversity and geomophological features as pointed out earlier, may suggest the essential measures that can be used as predictive factors for suitable reserved sites.

The ideal sites that could be proposed for establishment of reserved areas are the section of reef along the north-west coast of Ko Lipe (Site A) and that along the south coast of Ko Adang (Site E). With respect to certain ecological criteria, these two sites have relatively large reef area with high diversity of fishes (Fig. 8), very high diversity of corals (N. Phongsuwan, personal communication), and the reef conditions are categorized as fair to good (PHONGSUWAN, 1999). Furthermore, these sites are located just in front of the Marine Fisheries Resources Conservation Station (Site A) and the Park Office (Site E). Hence, strict control and enforcement in order to eliminate fishing should be feasible. As suggested by KENCHINGTON (1988), rather than a large single protected area (block conservation), a network of smaller units of protected areas (matrix conservation) is a good alternative, and importantly, is much less daunting to the management planner. In order to establish such a network of units and to maintain reef resources for the whole area, it is also suggested to segregate the reserved sites among widely separated areas. The other potential sites to be selected for reserves may include the reef along the east coast of Ko Rawi (Site M) and that along the south-east coast of Ko Butang (Site O). Although these reefs are not very large, they meet certain ecological criteria, i.e. high fish diversity (Fig. 8) with good to very good reef conditions (PHONGSUWAN, 1999). Furthermore, these sites, especially Site M, are unique in being located in the path of strong tidal currents. Such a hydrodynamic feature should promote dispersion of larvae, particularly nearly settled larvae, to colonize down-stream reef sites within the area.

Farther into the future may lie the effective multiple use management for the Adang–Rawi island group, or for the Tarutao Marine National Park as a whole. This is a challenging task but will have never been possible without strong community involvement, co-management among stakeholders, and continuing effort once any management scheme has been implemented.

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Appendix. Checklist of reef-associated fishes of the Adang-Rawi Islands.

Key to symbols:
x = quantified on visual census transects.
+ = visual records without quantification (for cryptic species) or species observed outside the census area.
# = specimens collected.
– = not recorded.
* = note at the end of Appendix.

Family	Species	Present study			1994 survey
		Shore area	Reef flat	Reef slope	(reef slope)
Carcharhinidae	*Carcharhinus melanopterus*	–	–	+	–
Stegostomatidae	*Stegostoma varium*	–	–	x	–
Dasyatidae	*Dasyatis kuhlii*	–	+	+	–
	*[1]*Pastinachus sephen*	–	–	+	–
Myliobatidae	*[1]*Aetobatus narinari*	–	–	+	–
Acanthuridae	*Acanthurus leucosternon*	–	x	–	+
	Acanthurus lineatus	–	x	+	+
	Acanthurus mata	–	–	x	–
	*[1,2]*Acanthurus olivaceus*	–	–	–	+
	Acanthurus triostegus	–	x	–	–
	Acanthurus xanthopterus	–	+	+	–
	Ctenochaetus binotatus	–	–	x	–
	Ctenochaetus striatus	–	x	x	–
	Ctenochaetus strigosus	–	–	x	+
Apogonidae	*[1,2]*Apogon arenatus*	–	–	–	#
	*[1,2]*Apogon bandanensis*	#	–	x	–
	Apogon compressus	–	+	x	#, +
	Apogon cookii	–	#	+	–
	Apogon cyanosoma	–	x	x	+
	Apogon frenatus	–	–	–	#
	Apogon kallopterus	–	–	–	+
	*[1,2]*Apogon peritus*	–	–	–	+
	*[1,2]*Apogon* sp.1	–	–	+	–
	*[1]*Apogon trimaculatus*	–	–	x	+
	Apogon ventrifasciatus	–	–	x	–
	Archamia fucata	–	–	x	+
	Cheilodipterus artus	–	–	x	+
	Cheilodipterus macrodon	–	x	x	+
	Cheilodipterus quinquelineatus	–	x	x	+
	Fowleria variegata	–	#	–	–
	Rhabdamia gracilis	–	–	+	–
Atherinidae	*[1]*Atherinomorus duodecimalis*	#	–	–	–

Family	Species	Present study			1994 survey (reef slope)
		Shore area	Reef flat	Reef slope	
Aulostomidae	*Aulostomus chinensis*	–	–	x	#, +
Balistidae	*[1]*Abalistes stellatus*	–	–	+	+
	Balistapus undulatus	–	x	x	–
	Balistoides viridescens	–	+	+	–
	Odonus niger	–	–	–	+
	*[1,2]*Pseudobalistes flavimarginatus*	–	–	+	–
	Sufflamen chrysopterus	–	–	x	–
	Sufflamen frenatus	–	–	+	–
Belonidae	*Tylosurus crocodilus crocodilus*	–	x	x	–
Blenniidae	*Atrosalarias fuscus fuscus*	–	+	–	–
	*[1]*Blenniella leopardus*	–	#	–	–
	Cirripectes filamentosus	–	+	–	–
	Ecsenius bicolor	–	–	+	#, +
	Ecsenius lubbocki	–	+	+	#, +
	Istiblennius dussumieri	#	–	–	–
	*[1,2]*Laiphognathus multimaculatus*	–	–	–	#
	Meiacanthus smithi	–	–	+	#, +
	Omobranchus elongatus	–	#	–	–
	Omobranchus obliquus	#	#	–	–
	Plagiotremus phenax	–	–	+	–
	Plagiotremus rhinorhynchos	–	+	+	–
	Salarias fasciatus	–	#, +	–	–
	Salarias guttatus	–	#, +	–	–
Bythitidae	*[1]*Dinematichthys iluocoeteoides*	–	–	–	#
Caesionidae	*Caesio caerulaurea*	–	x	x	+
	Caesio cuning	–	x	x	#, +
	Caesio lunaris	–	x	x	–
	Caesio xanthonota	–	–	x	–
	Pterocaesio chrysozona	–	x	x	+
	*[1,2]*Pterocaesio pisang*	–	–	x	+
	*[1]*Pterocaesio tessellata*	–	–	x	–
Carangidae	*Atule mate*	–	–	+	+
	Carangoides ferdua	–	–	x	#, +
	*[1]*Carangoides plagiotaenia*	–	–	–	#
	Caranx ignobilis	–	–	–	#
	Caranx sexfasciatus	–	–	+	–
	Elagatis bipinnulatus	–	–	x	–
	Selaroides leptolepis	–	–	x	#
Carapidae	*[1,2]*Onuxodon parvibranchium*	–	–	–	#
Chaetodontidae	*Chaetodon andamanensis*	–	x	x	+
	Chaetodon auriga	–	x	–	+
	Chaetodon collare	–	x	x	#, +

Family	Species	Present study			1994 survey (reef slope)
		Shore area	Reef flat	Reef slope	
	Chaetodon lineolatus	–	x	–	–
	Chaetodon melannotus	–	–	x	+
	Chaetodon octofasciatus	–	x	x	+
	Chaetodon rafflesi	–	x	x	+
	Chaetodon triangulum	–	x	x	#, +
	Chaetodon trifascialis	–	x	x	+
	Chaetodon trifasciatus	–	x	x	+
	Chaetodon vagabundus	–	x	x	+
	Coradion chrysozonus	–	–	x	#
	Heniochus acuminatus	–	–	x	+
	Heniochus pleurotaenia	–	–	x	–
	Heniochus singularius	–	–	+	+
Cirrhitidae	*Cirrhitichthys oxycephalus*	–	–	+	–
Clupeidae	*Spratelloides delicatulus*	–	x	–	+
	*[1]*Spratelloides gracilis*	–	–	–	#, +
Diodontidae	*Diodon histrix*	–	x	x	–
	Diodon liturosus	+	–	+	+
Echeneidae	*Echeneis naucrates*	–	–	–	+
Ephippidae	*Platax teira*	–	x	+	+
Fistulariidae	*Fistularia commersoni*	–	x	x	–
Gerreidae	*[1]*Gerres oblongus*	–	+	–	#, +
	Gerres oyena	–	#, x	+	–
Gobiidae	*Amblyeleotris diagonalis*	–	–	+	–
	Amblyeleotris downingi	–	–	+	–
	*[1,2]*Amblyeleotris latifasciata*	–	–	+	–
	*[1,2]*Amblyeleotris periophthalmus*	–	–	+	–
	Amblyeleotris steinitzi	–	–	+	+
	Amblygobius hectori	–	+	+	#, +
	Amblygobius nocturnus	–	–	+	–
	Amblygobius semicinctus	–	+	–	+
	*[1,2]*Asterropteryx ensiferus*	–	–	–	#
	Asterropteryx semipunctatus	–	#, +	+	#
	*[1,2]*Asterropteryx* sp.1	–	–	+	–
	Bathygobius cocosensis	#	–	–	–
	Bathygobius fuscus	#	–	–	–
	*[1,2]*Cabillus tongarevae*	–	–	–	#
	Callogobius sp.1	#	#	–	–
	Cryptocentrus fasciatus	–	–	+	–
	Cryptocentrus leptocephalus	–	+	–	–
	*[1,2]*Cryptocentrus leucostictus*	–	+	–	–
	Cryptocentrus sp.1	–	–	+	–
	Cryptocentrus strigilliceps	–	+	+	–

Family	Species	Present study			1994 survey (reef slope)
		Shore area	Reef flat	Reef slope	
	Ctenogobiops crocineus	–	+	+	#
	Ctenogobiops pomastictus	–	+	+	#
	[1,2]Eviota punctulata	–	–	–	#
	Eviota queenslandica	–	#	–	#
	Eviota sebreei	–	–	#, +	#
	[1,2]Eviota sigillata	–	–	#, +	#
	[1,2]Eviota spilota	–	–	–	#
	Eviota zebrina	–	–	–	#
	Exyrias bellissimus	–	–	–	#
	Fusigobius neophytes	–	–	–	#
	[1,2]Fusigobius signipinnis	–	–	+	–
	Fusigobius spp.	–	+	+	–
	Gnatholepis anjerensis	–	#, +	–	–
	Gobiodon histrio	–	–	–	#
	Gobiodon quinquestrigatus	–	–	–	#
	Gobiodon rivulatus	–	–	#	#
	[1,2]Gobiodon sp.1	–	–	#	–
	[1]Gobiopsis quinquecincta	#	–	–	–
	Istigobius decoratus	–	+	+	+
	Istigobius goldmanni	–	#, +	–	#
	Istigobius ornatus	#	#, +	–	–
	[1,2]Oplopomus caninoides	–	–	+	–
	Papillogobius melanobranchus	#	–	–	–
	[1,2]Sueviota lachneri	–	–	–	#
	[1,2]Trimma okinawae	–	–	–	#
	Trimma striata	–	+	+	#
	[1,2]Trimma winterbottomi	–	–	–	#
	[1,2]Valenciennea limicola	–	–	+	–
	Valenciennea muralis	–	+	+	+
	Valenciennea puellaris	–	–	+	–
	Valenciennea sexguttata	–	#, +	+	#, +
	Vanderhorstia ambanoro	–	–	+	–
	[1,2]Vanderhorstia ornatissima	–	–	+	–
Grammistidae	*Diploprion bifasciatum*	–	–	+	#
Haemulidae	*Diagramma pictum*	–	–	x	+
	Plectorhinchus chaetodonoides	–	x	x	+
	Plectorhinchus gibbosus	–	x	+	+
	Plectorhinchus vittatus	–	–	x	–
Holocentridae	*[1,2]Myripristes berndti*	–	–	x	–
	[1,2]Myripristes botche	–	–	–	#
	Myripristes hexagona	–	x	x	+
	Neoniphon sammara	–	–	–	+

Family	Species	Present study			1994 survey (reef slope)
		Shore area	Reef flat	Reef slope	
	Sargocentron caudimaculatum	–	–	–	+
	*[1,2]*Sargocentron cornutum*	–	#	+	–
	*[1,2]*Sargocetron melanospilos*	–	–	–	+
	Sargocentron rubrum	–	#, x	x	#, +
Kyphosidae	*Kyphosus cinerascens*	–	x	x	+
	Kyphosus vaigiensis	–	x	x	–
Labridae	*Anampses caeruleopunctatus*	–	–	x	–
	Anampses mleagrides	–	–	–	+
	Bodianus axillaris	–	–	x	+
	Bodianus diana	–	–	x	+
	Bodianus mesothorax	–	x	x	+
	Bodianus neilli	–	x	x	+
	Cheilinus chlorurous	–	x	x	+
	Cheilinus fasciatus	–	x	x	+
	Cheilinus oxycephalus	–	–	x	–
	Cheilinus trilobatus	–	x	x	–
	Cirrhilabrus cyanopleura	–	x	x	+
	Coris batuensis	–	x	x	#, +
	Diproctacanthus xanthurus	–	x	x	–
	Epibulus insidiator	–	x	x	#, +
	Gomphosus caeruleus	–	x	x	+
	Halichoeres argus	–	#, x	–	+
	Halichoeres chloropterus	–	x	+	#, +
	Halichoeres hortulanus	–	x	x	#, +
	Halichoeres kallochroma	–	–	x	–
	Halichoeres marginatus	–	#, x	x	#, +
	Halichoeres nebulosus	–	+	–	–
	Halichoeres nigrescens	–	+	–	–
	Halichoeres scapularis	–	#, x	x	+
	Halichoeres timorensis	–	x	x	–
	Halichoeres vrolikii	–	x	x	#, +
	Hemigymnus fasciatus	–	x	x	+
	Hemigymnus melapterus	–	x	x	+
	Labrichthys unilineatus	–	x	x	+
	Labroides bicolor	–	–	x	+
	Labroides dimidiatus	–	x	x	+
	Leptojulis cyanopleura	–	–	x	+
	Macropharyngodon ornatus	–	–	x	–
	Oxycheilinus digrammus	–	x	x	#, +
	Pseudocheilinus hexataenia	–	–	x	+
	Pseudodax moluccanus	–	–	+	–
	Pteragogus cryptus	–	–	x	–

Family	Species	Present study			1994 survey (reef slope)
		Shore area	Reef flat	Reef slope	
	Stethojulis bandanensis	–	x	–	–
	Stethojulis interrupta	–	x	x	–
	Stethojulis trilineata	–	x	x	#, +
	*[1]*Thalassoma amblycephalum*	–	–	x	–
	Thalassoma hardwicke	–	x	x	+
	Thalassoma janseni	–	x	–	–
	Thalassoma lunare	–	x	x	#, +
Lethrinidae	*[1,2]*Lethrinus crocineus*	–	x	–	#
	Lethrinus erythropterus	–	x	x	+
	Lethrinus harak	–	–	–	+
	Lethrinus lentjan	–	+	–	#
	Lethrinus ornatus	–	x	–	–
Lutjanidae	*Lutjanus argentimaculatus*	–	–	+	–
	Lutjanus biguttatus	–	x	x	#, +
	Lutjanus decussatus	–	#, x	x	+
	Lutjanus fulviflamma	#	x	x	+
	Lutjanus fulvus	–	–	x	–
	Lutjanus gibbus	–	–	+	–
	Lutjanus lemniscatus	–	–	+	+
	Lutjanus lutjanus	–	x	x	–
	Lutjanus monostigma	–	x	+	#
	Lutjanus quinquelineatus	–	–	x	#
	Lutjanus russelli	–	x	x	#, +
	Lutjanus vitta	–	–	+	–
Microdesmidae	*Parioglossus philippinus*	–	+	–	–
	Ptereleotris microlepis	–	–	+	–
Monacanthidae	*Aluterus scriptus*	–	–	x	–
	Oxymonacanthus longirostris	–	–	+	–
Monodactylidae	*Monodactylus argenteus*	–	–	+	–
Mugilidae	*Moolgarda seheli*	–	+	+	–
	Oedalechilus labiosus	#	–	–	–
Mullidae	*Mulloidichthys flavolineatus*	–	–	–	+
	Parupeneus barberinus	–	x	x	#, +
	Parupeneus heptacanthus	–	–	+	–
	Parupeneus macronema	–	x	x	+
	Upeneus tragula	–	x	x	+
Muraenidae	*[1]*Echidna nebulosa*	#	–	–	–
	Gymnothorax flavimarginatus	–	–	x	–
	Gymnothorax javanicus	–	x	x	+
	Gymnothorax richardsoni	–	#	–	–
	*[1,2]*Gymnothorax pictus*	–	#	–	–
	Gymnothorax pseudothyrsoideus	–	–	–	#

Family	Species	Present study			1994 survey
		Shore area	Reef flat	Reef slope	(reef slope)
	*[1,2]*Gymnothorax zonipectis*	–	#	–	–
	*[1,2]*Uropterygius concolor*	–	#	–	–
Nemipteridae	*Scolopsis affinis*	–	–	x	#, +
	Scolopsis bilineatus	–	#, x	x	+
	Scolopsis ciliatus	–	+	x	+
	Scolopsis lineatus	#	x	x	+
	Scolopsis margaritifer	–	x	x	+
	Scolopsis monogramma	–	x	x	+
	Scolopsis vosmeri	–	–	x	+
Ophichthidae	*[1,2]*Myrichthys colubrinus*	–	–	+	–
Ostraciidae	*Ostracion cubicus*	–	x	x	+
Pempheridae	*Pempheris vanicolensis*	–	x	x	+
Pinguipedidae	*Parapercis clathata*	–	+	–	–
	Parapercis hexophthalma	–	x	x	+
	Parapercis millepunctata	–	–	+	+
	Parapercis xanthozona	–	–	+	–
Plesiopidae	*[1,2]*Calloplesiops altivelis*	–	–	–	+
	*[1]*Plesiops caeruleolineatus*	–	#	–	–
	Plesiops corallicora	#	–	–	–
Pomacanthidae	*Centropyge eibli*	–	x	x	+
	Centropyge multispinis	–	–	x	–
	Pomacanthus annularis	–	–	x	+
	Pomacanthus imperator	–	–	x	+
Pomacentridae	*Abudefduf begalensis*	–	x	x	+
	Abudefduf notatus	–	x	–	+
	Abudefduf sordidus	#	x	–	+
	Abudefduf vaigiensis	–	#, x	x	+
	Amblyglyphidodon aureus	–	–	x	–
	Amblyglyphidodon leucogaster	–	x	x	#, +
	Amphiprion akallopisos	–	x	x	#, +
	Amphiprion clarkii	–	x	x	+
	Amphiprion ephippium	–	x	x	+
	Amphiprion ocellaris	–	x	x	#, +
	Cheiloprion labiatus	–	x	x	–
	Chromis atripectoralis	–	x	x	#, +
	Chromis cinerascens	–	–	x	–
	Chromis flavipectoralis	–	–	x	+
	Chromis opercularis	–	–	x	–
	Chromis ternatensis	–	–	x	#, +
	Chromis viridis	–	–	x	–
	Chromis weberi	–	–	x	+
	Chrysiptera rollandi	–	x	x	#, +

Family	Species	Present study			1994 survey (reef slope)
		Shore area	Reef flat	Reef slope	
	Chrysiptera unimaculata	–	#, x	–	+
	Dascyllus aruanus	–	x	–	–
	Dascyllus carneus	–	–	x	+
	Dascyllus trimaculatus	–	+	x	#, +
	Dischistodus perspicillatus	–	x	x	. +
	Neoglyphidodon melas	–	x	x	+
	Neoglyphidodon nigroris	–	x	x	+
	Neopomacentrus anabatoides	–	x	x	+
	Neopomacentrus azysron	–	x	x	+
	Neopomacentrus cyanomos	–	–	x	+
	Neopomacentrus filamentosus	–	x	x	+
	Plectroglyphidodon lacrymatus	–	x	x	+
	Pomacentrus adelus	–	#, x	x	#, +
	Pomacentrus amboinensis	–	x	x	+
	Pomacentrus azuremaculatus	–	x	x	+
	Pomacentrus chrysurus	–	x	x	+
	Pomacentrus lepidogenys	–	–	x	+
	Pomacentrus moluccensis	–	x	x	#, +
	Pomacentrus nagasakiensis	–	–	x	+
	Pomacentrus pavo	–	x	x	#, +
	Pomacentrus philippinus	–	x	x	+
	Pomacentrus similis	–	x	x	+
	Pomacentrus tripunctatus	–	#, x	–	–
	Stegastes nigricans	–	x	x	+
	Stegastes obreptus	–	x	–	+
Priacanthidae	*Priacanthus hamrur*	–	–	x	–
Pseudochromidae	*[1]*Pseudochromis andamanensis*	–	–	+	#
	*[1,2]*Pseudoplesiops rosae*	–	–	–	#
Scaridae	*Chlorurus capistratoides*	–	x	x	–
	Chlorurus sordidus	–	x	x	+
	Chlorurus strongylocephalus	–	+	x	–
	Chlorurus troschelii	–	x	x	+
	Scarus ghobban	–	x	x	+
	Scarus niger	–	x	x	#, +
	Scarus prasiognathos	–	x	x	–
	Scarus quoyi	–	x	x	+
	Scarus rubroviolaceus	–	x	x	–
	Scarus russelii	–	x	x	–
	Scarus scaber	–	x	–	–
	*[1,2]*Scarus* sp.1	–	+	x	+
	Scarus tricolor	–	x	x	–
Scombridae	*[1]*Euthynnus affinis*	–	–	+	–

Family	Species	Present study			1994 survey (reef slope)
		Shore area	Reef flat	Reef slope	
Scorpaenidae	*Dendrochirus zebra*	–	–	+	+
	*[1,2]*Parascorpaena aurita*	–	#	–	#
	Pterois antennata	–	–	x	+
	Pterois miles	–	–	x	#, +
	*[1,2]*Scorpaenodes albiensis*	–	–	–	#
	Scorpaenodes guamensis	–	–	–	#
	*[1,2]*Scorpaenodes varipinnis*	–	–	–	#
	*[1,2]*Scorpaenopsis diabolus*	–	–	+	–
Serranidae	*Aethaloperca rogaa*	–	–	x	+
	Anyperodon leucogrammicus	–	x	x	+
	Cephalopholis argus	–	x	x	+
	Cephalopholis boenak	–	#	x	#, +
	Cephalopholis formosa	–	#, x	+	#
	Cephalopholis miniata	–	–	x	#, +
	Cephalopholis polyspila	–	x	x	#, +
	*[1,3]*Cromileptes altivelis*	–	–	+	–
	*[1]*Epinephelus areolatus*	–	–	+	#, +
	Epinephelus caeruleopunctatus	#	x	x	+
	Epinephelus coioides	–	–	+	–
	Epinephelus erythrurus	–	x	x	+
	Epinephelus fuscoguttatus	–	–	+	+
	Epinephelus ongus	–	#, x	+	+
	Epinephelus quoyanus	–	#, x	x	+
	Plectropomus pessuliferus pessuliferus	–	–	+	+
Siganidae	*Siganus canaliculatus*	–	x	x	+
	Siganus guttatus	–	x	x	+
	Siganus javus	–	x	x	+
	Siganus puelloides	–	+	+	+
	Siganus vermiculatus	–	–	+	–
Solenostomidae	*[1]*Solenostomus paradoxus*	–	–	–	#
Sphyraenidae	*Sphyraena baracuda*	–	–	x	–
	Sphyraena obtusata	–	–	x	+
Syngnathidae	*Bhanotia fasciolata*	–	#	–	–
	*[1]*Coeroichthys brachysoma*	–	#	–	–
	Corythoichthys haematopterus	–	#, +	–	+
	*[1]*Corythoichthys schultzi*	–	–	–	#
	*[1,2]*Doryrhamphus janssi*	–	–	–	#
	*[1,2]*Halicampus spinirostris*	–	–	–	#
Synodontidae	*Synodus variegatus*	–	x	x	+
Tetraodontidae	*[1]*Arothron immaculatus*	–	–	–	#
	Arothron nigropunctatus	–	x	x	+

Family	Species	Present study			1994 survey (reef slope)
		Shore area	Reef flat	Reef slope	
	Arothron stellatus	–	–	x	–
	Canthigaster solandri	–	–	x	+
Trachipteridae	*[1,4]Zu cristatus	–	+	–	–
Tripterygiidae	*[1,2]Enneapterygius tutuilae*	–	–	–	#
	Enneapterygius sp.	#	–	–	–
	[1,2]Helcogramma springeri	–	–	–	#
	Helcogramma striata	–	+	+	#
Zanclidae	*Zanclus cornutus*	–	x	x	+

Note:

1) Species had never been reported in the following works: Satapoomin, 1993; 1997; 1999; and Satapoomin & Chansang, in press.
2) New records for the Andaman Sea coast of Thailand.
3) A few individuals were kept in the stocking cages of the local fishermen at Ko Lipe.
4) An offshore epipelagic species. A small young individual, ca. 15-cm SL, was found drifting onto the reef flat of Ko Lipe during the abnormal cool sea temperature in February 1998.