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INTERRELATION OF ICHTHYOFAUNA FROM A SEAGRASS MEADOW AND CORAL REEF IN THE PHILIPPINES

by

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ABSTRACT. - Tropical seagrass meadows associated with coral reefs are utilised both daily and seasonally as feeding ground and nursery area by reef fishes. The interrelation of seagrass meadow and coral reef ichthyofauna was studied in Malatapay, Negros Oriental, Philippines. Sampling was conducted with a beach seine in a seagrass meadow at two distances (50 m and 250 m) from a coral reef at day and night. 115 species belonging to 70 genera and 42 families were identified. Hierarchical clustering by Bray-Curtis similarity of samples shows a day and a night group with sub-groups depending on distance to the coral reef. Additional observations by visual censuses support these results. Resident and diurnally active species of the seagrass meadow belong to the families Labridae, Scaridae, Siganidae, Mullidae, Pomacentridae and Gobiidae. Nocturnally active and resident species belong to the families Bothidae, Soleidae, Callionymidae, Scorpaenidae and Lethrinidae. Apogonidae, Plotosidae, Holocentridae, Diodontidae, Congridae, Muraenidae, Ophichthidae and Tetraodontidae migrate into the seagrass meadow at night to forage. Length frequencies indicate that Mullidae, Scorpaenidae, Lethrinidae and Plotosidae utilise the seagrass meadow as a nursery area. This demonstrates the interrelation of these habitats and the importance of seagrass meadows for coral reef fishes.

RÉSUMÉ. - Relations entre l'ichtyofaune d'un herbier de phanérogammes et celle d'un récif corallien aux Philippines.

Les herbiers de phanérogames tropicaux qui sont associés aux récifs coralliens sont utilisés par les poissons du récif comme aire d'alimentation et de nurserie. Cette étude examine les corrélations entre les herbiers de phanérogames et les poissons du récif corallien à Malatapay, Negros Oriental, Philippines. L'échantillonnage a été réalisé avec une senne de plage dans l'herbier, à 50 et 250 m du récif corallien. Les échantillons ont été pris pendant le jour et la nuit. 115 espèces appartenant à 70 genres et 42 familles ont été identifiées. La classification hiérarchique de similarité de Bray-Curtis des échantillons met en évidence un groupe d'espèces diurnes et un groupe d'espèces nocturnes avec des sous-groupes dépendant de la distance au récif corallien. Les observations visuelles confirment ce résultat. Les poissons ayant une activité diurne appartiennent aux familles suivantes: Labridae, Scaridae, Siganidae, Mullidae, Pomacentridae et Gobiidae, et les espèces ayant une activité nocturne font partie des Bothidae, Soleidae, Callionymidae, Scorpaenidae et Lethrinidae. Les Apogonidae, Plotosidae, Holocentridae, Diodontidae, Congridae, Muraenidae, Ophichthidae et Tetraodontidae migrent vers l'herbier durant la nuit pour y rechercher de la nourriture. Les fréquences de tailles indiquent que les Mullidae, Scorpaenidae, Lethrinidae et Plotosidae utilisent l'herbier comme aire de nurserie. Cela montre les rapports étroits entre ces habitats et l'importance des herbiers pour les poissons du récif.

Key-words. - Ichthyofauna, ISEW, Philippines, Seagrass meadow, Coral reef, Migration, Feeding ground, Nursery area.

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Tropical seagrass meadows are known as important nursery areas and feeding ground for fishes from adjacent coral reefs. They are seasonal residents in their early life stages or diurnal migrating visitors (Jones and Chase, 1975; Weinstein and Heck, 1979; Ogden and Gladfelter, 1983; Heck and Weinstein, 1989; Parrish, 1989). Many reef fishes migrate from reefs at night into seagrass meadows to forage, and are followed by piscivores. These predators from the reef are more common in seagrass meadows associated with coral reefs than in seagrass meadows associated with other habitats (Weinstein and Heck, 1979; Robblee and Zieman, 1984; Bell and Pollard, 1989). Due to these migrations the composition of seagrass meadow fish fauna is influenced by adjacent coral reefs. Connection of these habitats by fishes leads to a transport of biomass, organic substance and nutrients from seagrass meadows into coral reefs (Ogden, 1980; Ogden and Gladfelter, 1983; Meyer and Schulz, 1985; Parrish, 1989; Brouns and Heijs, 1991). Studies in the Caribbean have shown that the biomass of fishes is higher in coral reefs adjacent to seagrass meadows than in reefs without seagrass beds (Birkeland, 1985). Comparison of fisheries from different coral reef regions suggests that coral reefs with extended shallow water habitats, such as seagrass meadows or mangroves, yield the highest catch. Reefs with a ratio of shallow water habitat to coral reef of 1:1 or more are very productive (Marshall, 1985).

In the Philippine coastal waters seagrass meadows cover an area of 10,000 to 50,000 km^2. Transfer of findings from the well investigated Caribbean seagrass meadows to the Philippines suggest that 85% of commercial important fish species spend a part of their life cycle in seagrass meadows (Thorhaug and Cruz, 1988).

This study was conducted to investigate spatial and temporal patterns of seagrass meadow fish fauna and its relationship to the fish community of adjacent coral reefs.

MATERIAL AND METHODS

The study site Malatapay is located in the southern part of Negros Oriental (9°07'N, 123°12'E) adjacent to the Mindanao Sea in the Central Visayas Region, Philippines (Fig. 1). The seagrass meadow studied is situated between two coral reefs (Fig. 1) and is mainly composed of the seagrass species *Syringodium isoetifolium*, *Halodule universis* and *Cymodocea serrulata*. Water depth ranged from 1.0 to 10.0 m, with an average depth of 3 m at the sampled stations. The sampled area includes the sand flat between the seagrass meadow and the beach. The reference coral reef in this study is located at the right side of the seagrass meadow, close to station 1 (Fig. 1). It is assumed that the artificial reef does not influence station 2, because it is in a poor condition. The constructions of tires do not show any overgrowth with corals or other benthic organisms and only a small fish community exists.

Sampling was conducted from July to September 1995 with a beach seine of 30 m length, 1.5 - 2.5 m height and with a mesh size of 2 mm. A total of 74 samples were taken in the seagrass meadow during six 24 h cycles in two different distances (50 m and 250 m) from the coral reef (Table I). The length of each specimen was recorded and, if preservation was necessary, samples were frozen. Species identification was based on literature by Gloerfelt-Tarp and Kailola (1984), Lieske and Myers (1994), Randall *et al.* (1990) and Rau and Rau (1980).

During day, additional data were collected with the visual census technique based on English *et al.* (1994). A total of 36 visual censi was conducted by snorkelling on a

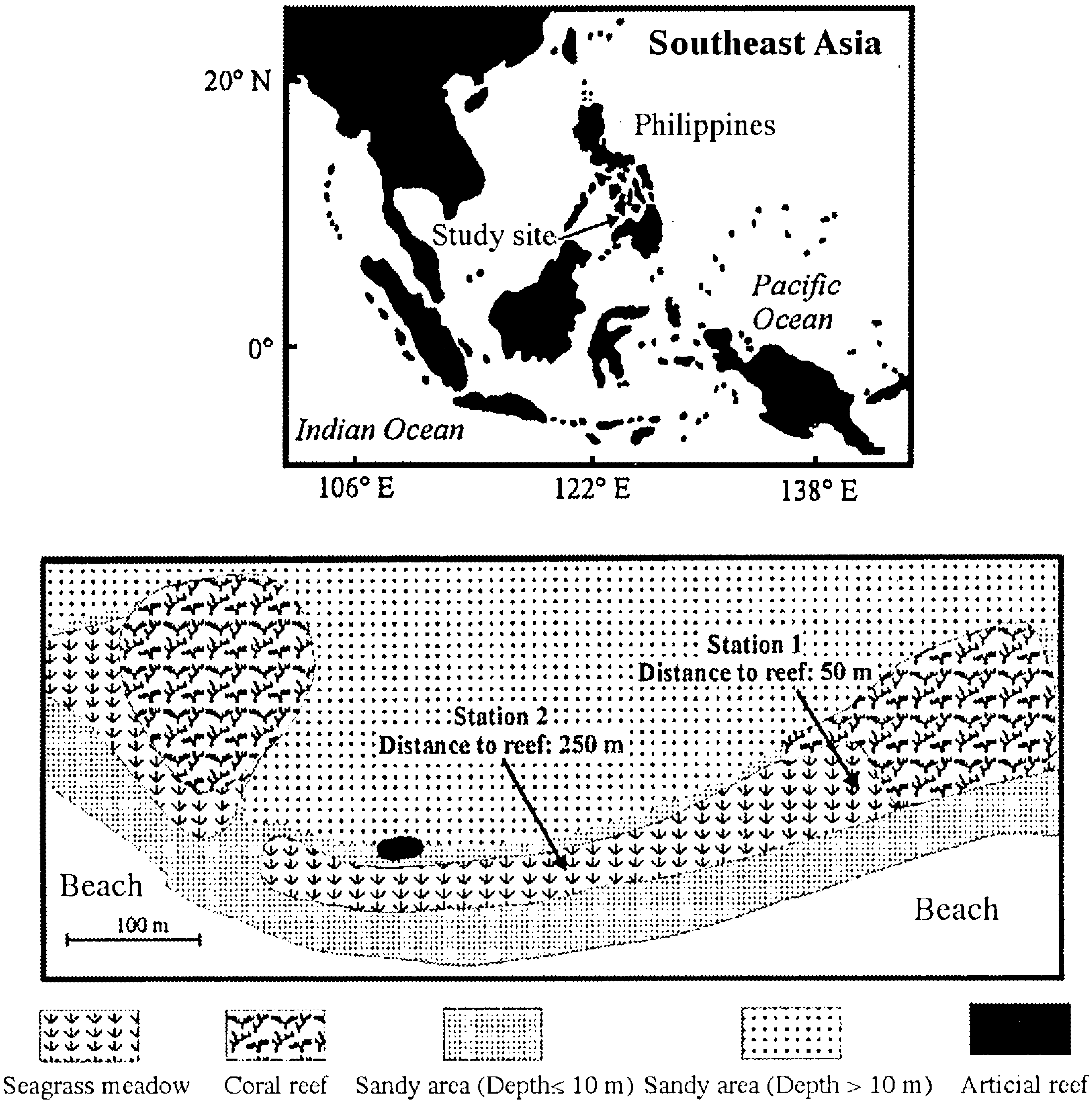

Fig. 1. - Study site. **A:** map of Southeast Asia; **B**: Bay of Malatapay, Negros Oriental, Philippines.

Table I. - Sampling strategy: number of samples taken in the seagrass meadow by beach seine and visual census at station 1 and station 2 during day and night (sunset: 18:30; sunrise: 5:30).

	Day			Night		
	After sunrise 7:00-7:30	Noon 12:00-12:30	Before sunset 17:30-18:00	After sunset 20:00-20:30	Mid-night 00:00-00:30	Before sunrise 4:30-5:00
Beach seine, station 1, 50 m distance to coral reef	6	6	6	6	6	6
Beach seine, station 2, 250 m distance to coral reef	6	6	6	6	6	6
Visual census, station 1, 50 m distance to coral reef	6	6	6	–	–	–
Visual census, station 2, 250 m distance to coral reef	6	6	6	–	–	–

Fig. 2. - Hierarchical clustering: Sample similarity dendrogram of beach seine samples (n = 72; $\sqrt{\sqrt{}}$ transformation of data). Day; 50 m = day / distance to coral reef: 50 m. Day; 250 m = day / distance to coral reef: 250 m. Night; 50 m = night / dDistance to coral reef: 50 m. Night; 250 m: = night / distance to coral reef: 250 m.

100 m transect with a width of 10 m (= 1000 m^2) at the same stations where the beach seine was used (Table I). Four additional visual censi (50 x 5 m transects) were conducted

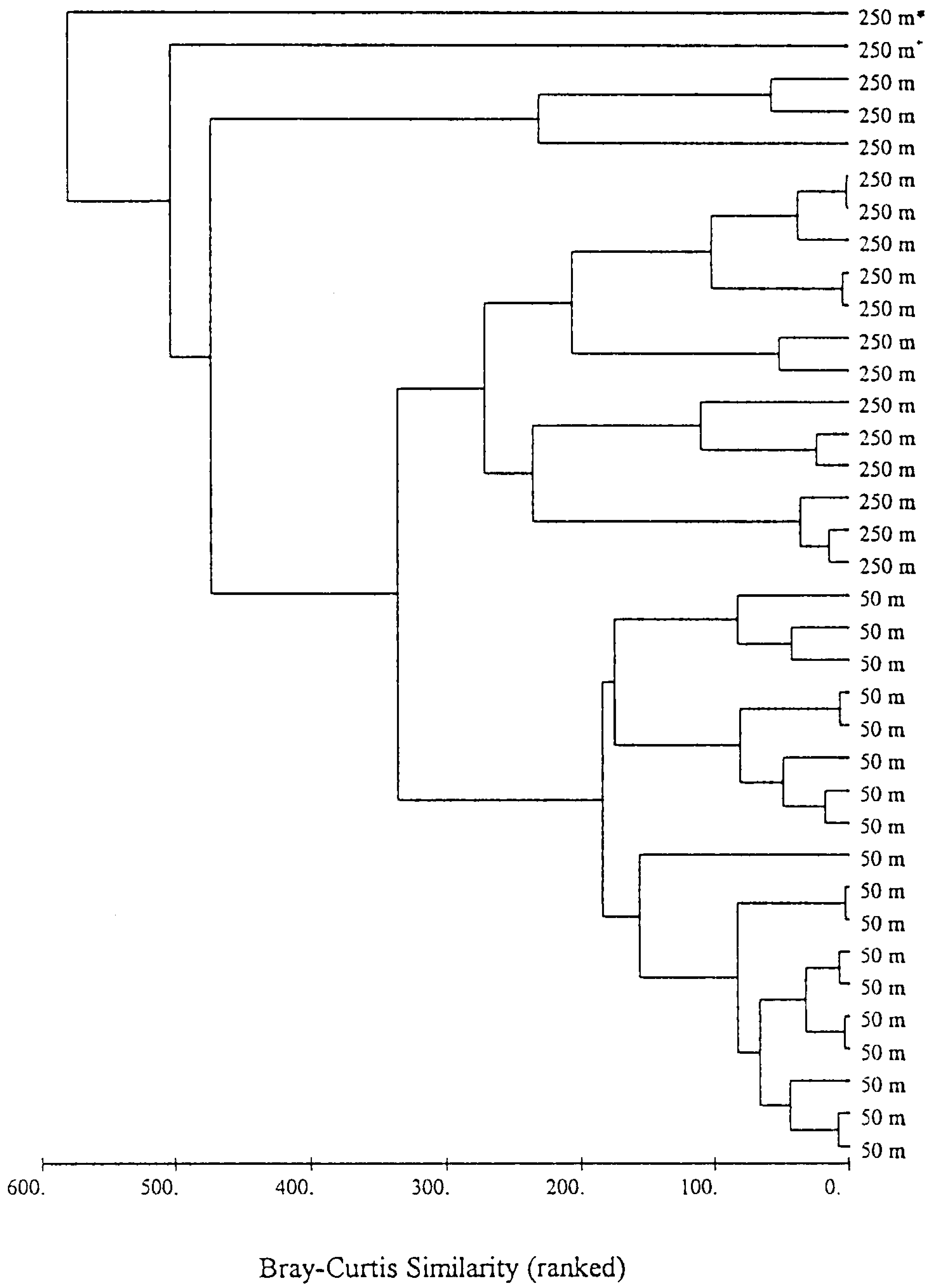

Fig. 3. - Hierarchical clustering: Sample similarity dendrogram of visual census data (n = 36; √√ transformation of data). 50 m = distance to coral reef: 50 m. 250 m = distance to coral reef: 250 m.

by B. Schirm and E. Cruz (CEMRINO) in both adjacent coral reefs at depth of 4 and 10 m. These data were used to compare size distribution of fishes between seagrass meadow and coral reef.

Hierarchical clustering and ANOSIM (Analysis of similarities) significance test are performed with PRIMER 4.0 software (Carr *et al.*, 1994). Hierarchical clustering of samples is based on Bray-Curtis similarities of √√ (square root) transformed abundance data of species. Hierarchical clustering of species is based on Bray-Curtis similarities of √√ transformed and standardised abundance data (Clarke and Warwick, 1994). The ANOSIM significance test compares the similarities of species composition between the samples

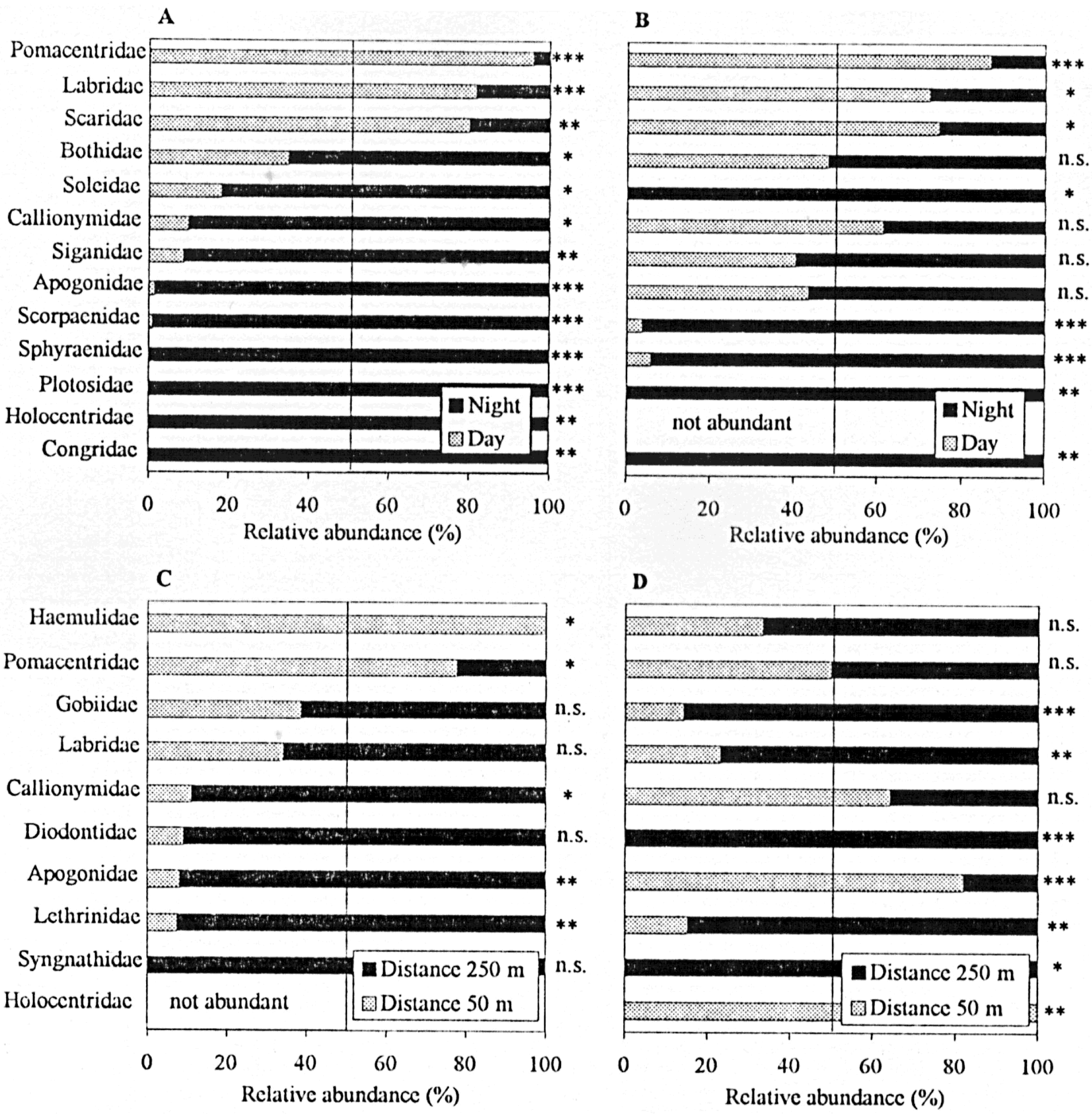

Fig. 4. - Diel (A, B) and spatial (C, D) variation in relative abundance of the seagrass meadow fish fauna in beach seine samples. **A**: Distance to coral reef 50 m; **B**: Distance to coral reef 250 m; **C**: Day; **D**: Night. Significance tested with Kruskal-Wallis ANOVA by ranks and median test: * = $0.05 \geq p \geq 0.01$; ** = $0.01 > p \geq 0.001$; *** = $p < 0.001$; n.s. = not significant.

and can give evidence for differences. Statistical significance tests such as Kruskal-Wallis ANOVA by ranks and median test were performed with STATISTICA software (Anon, 1993).

RESULTS

Pooled data of beach seining and visual census recorded a total of 115 species belonging to 70 genera and 42 families (Appendix). Apogonidae, Labridae, Plotosidae and Scorpaenidae are the most abundant families in pooled beach seine samples. Pooled diurnal visual census samples show the following ranking in abundance: Pomacentridae, Siganidae, Labridae and Apogonidae.

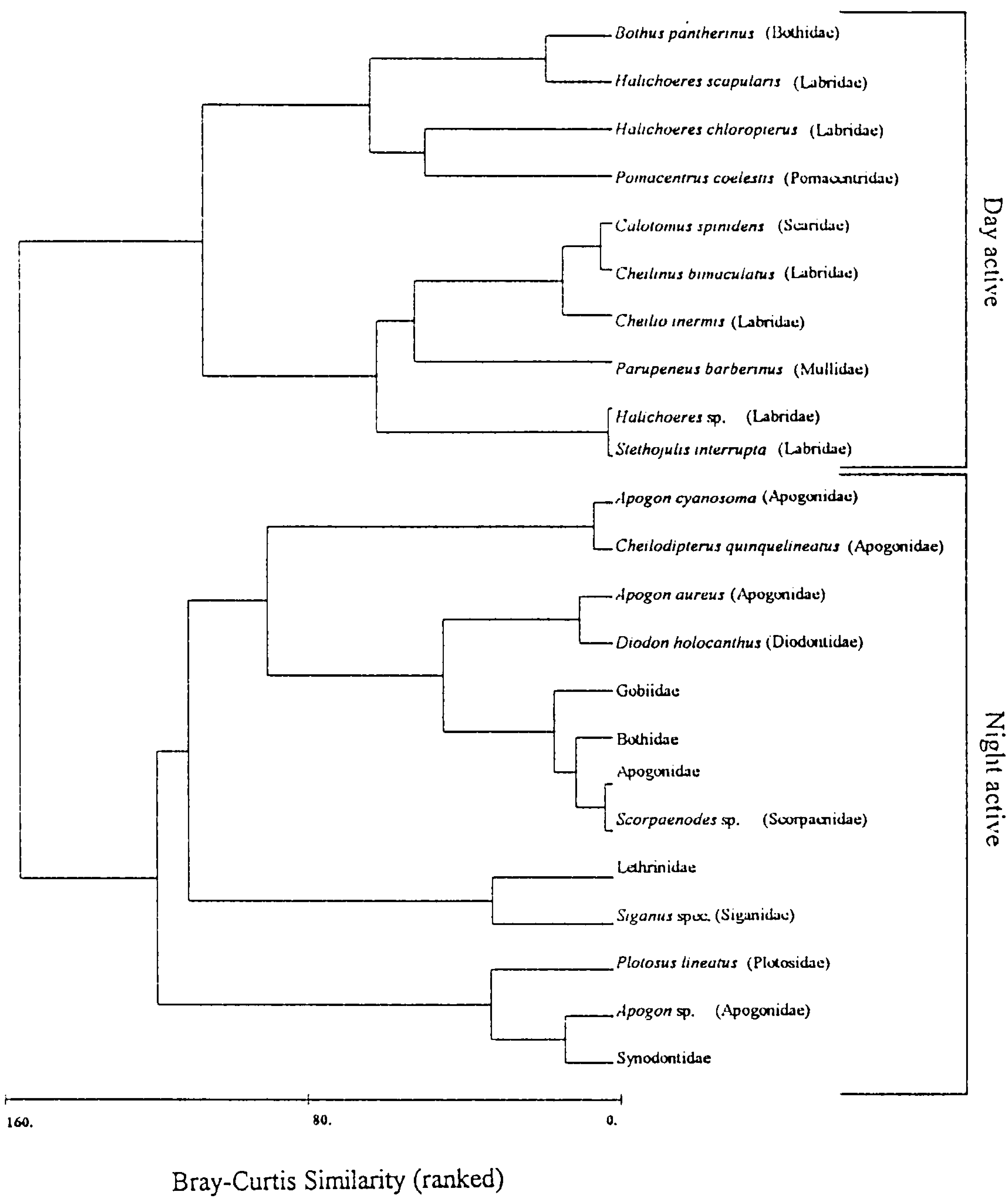

Fig. 5. - Species similarity dendrogram of beach seine samples (n = 72; species or families > 10% relative abundance in one sample).

Cluster analysis separates the beach seine samples into four clusters. Day and night cluster are divided into sub-cluster depending on distance to the coral reef (Fig. 2). Only one diurnal sample (Day; 250 m*) differs from this grouping and is assigned to the nocturnal samples. This is caused by a school of juvenile Siganidae which occurred only in this sample. Normally Siganidae were abundant only in nocturnal beach seine samples. No statement can be given to mismatches according to distances within the day and night cluster. The difference between the distances to the coral reef within these clusters is con

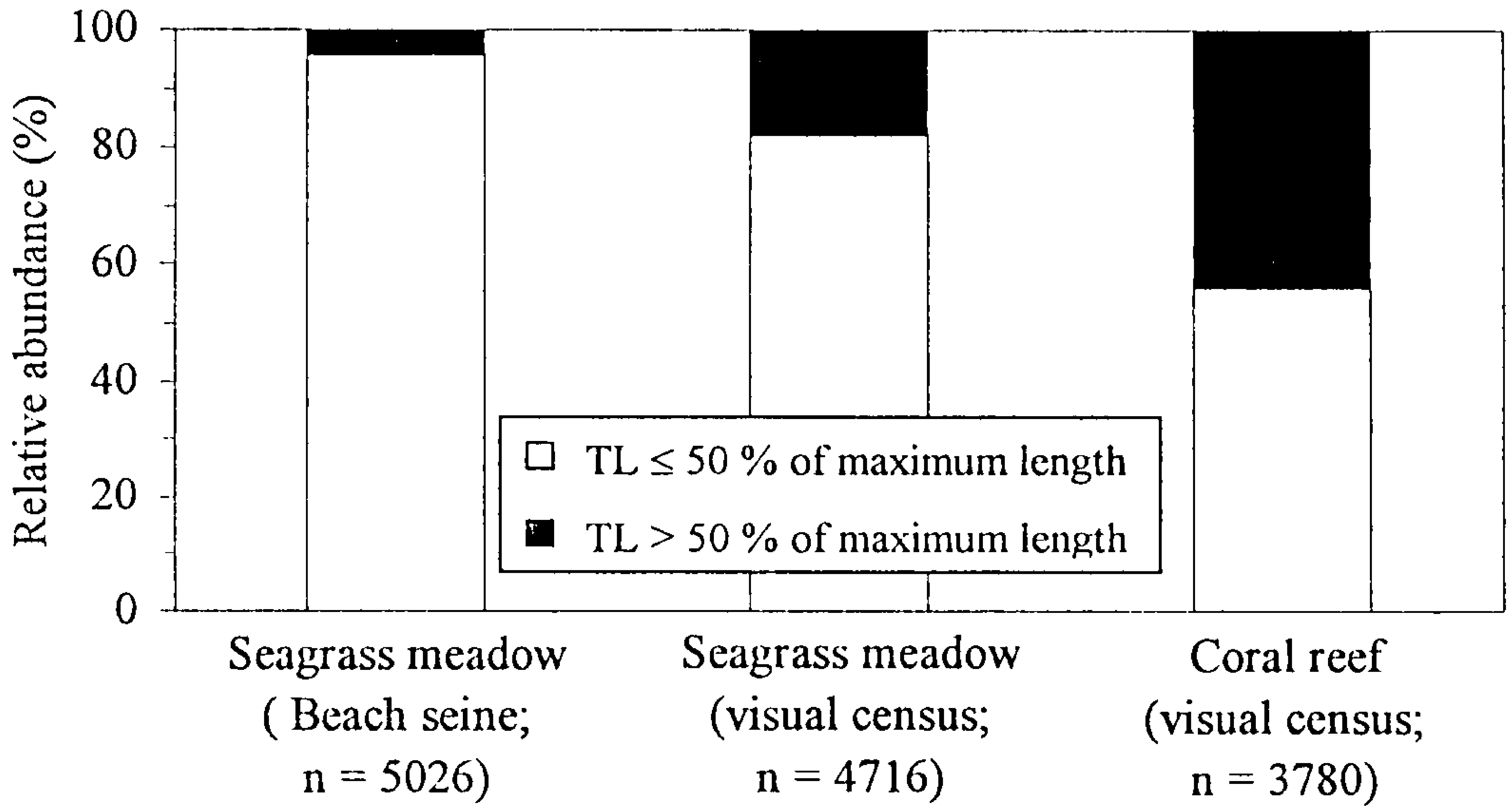

Fig. 6. - Relative abundance of juvenile fishes (TL ≤ 50% of maximum length) in the seagrass meadow and adjacent coral reef (pooled diurnal samples); maximum length based on Lieske and Myers (1994).

firmed with an ANOSIM significance test ($p < 0.005$). No difference is detected between the different times of the day and different times of the night by the cluster analysis.

Cluster analysis of visual census data shows a separation in two clusters according to the distance to the coral reef (Fig. 3). Five samples of the distance category 250 m do not fit into this pattern. Sample 250 m* shows the slightest similarity to all other samples because a school of 500 juvenile *Plotosus lineatus* was recorded. A reason for the poor similarity of sample 250 m+ was the low abundance of fishes in this census. The difference between the two distance categories is confirmed with an ANOSIM significance test ($p < 0.005$).

Relative abundance of fish families in beach seine samples during day and night reflects different pattern of activity (Fig. 4). Pomacentridae, Labridae and Scaridae show a significant higher relative abundance during day at both stations. Congridae, Plotosidae, Holocentridae, Scorpaenidae, Apogonidae, Sphyraenidae, Callionymidae, Siganidae, Bothidae and Soleidae show a significant higher relative abundance at night at both or one of the different stations. Muraenidae, Ophichthidae and Tetraodontidae were observed in low numbers in the seagrass meadow at night (Appendix). A species similarity dendrogram of beach seine catches separates the most abundant species into a day and a night active group (Fig. 5). Species of the day active group belong to the families Labridae, Scaridae, Pomacentridae and Mullidae. Night active species are members of the families Apogonidae, Diodontidae, Bothidae, Scorpaenidae, Lethrinidae, Plotosidae, and Synodontidae.

The occurrence of Siganidae in nocturnal beach seine samples did not reflect a night active behaviour. Visual census data indicate a diurnal activity. Nocturnal observations show that siganid species hide and rest between the blades of the seagrass. This leads to an increased vulnerability to the beach seine at night. The classification of Gobiidae into the night active group is also caused by the increased efficiency of the net at night. Visual census data also indicate that Gobiidae belong to the day active group.

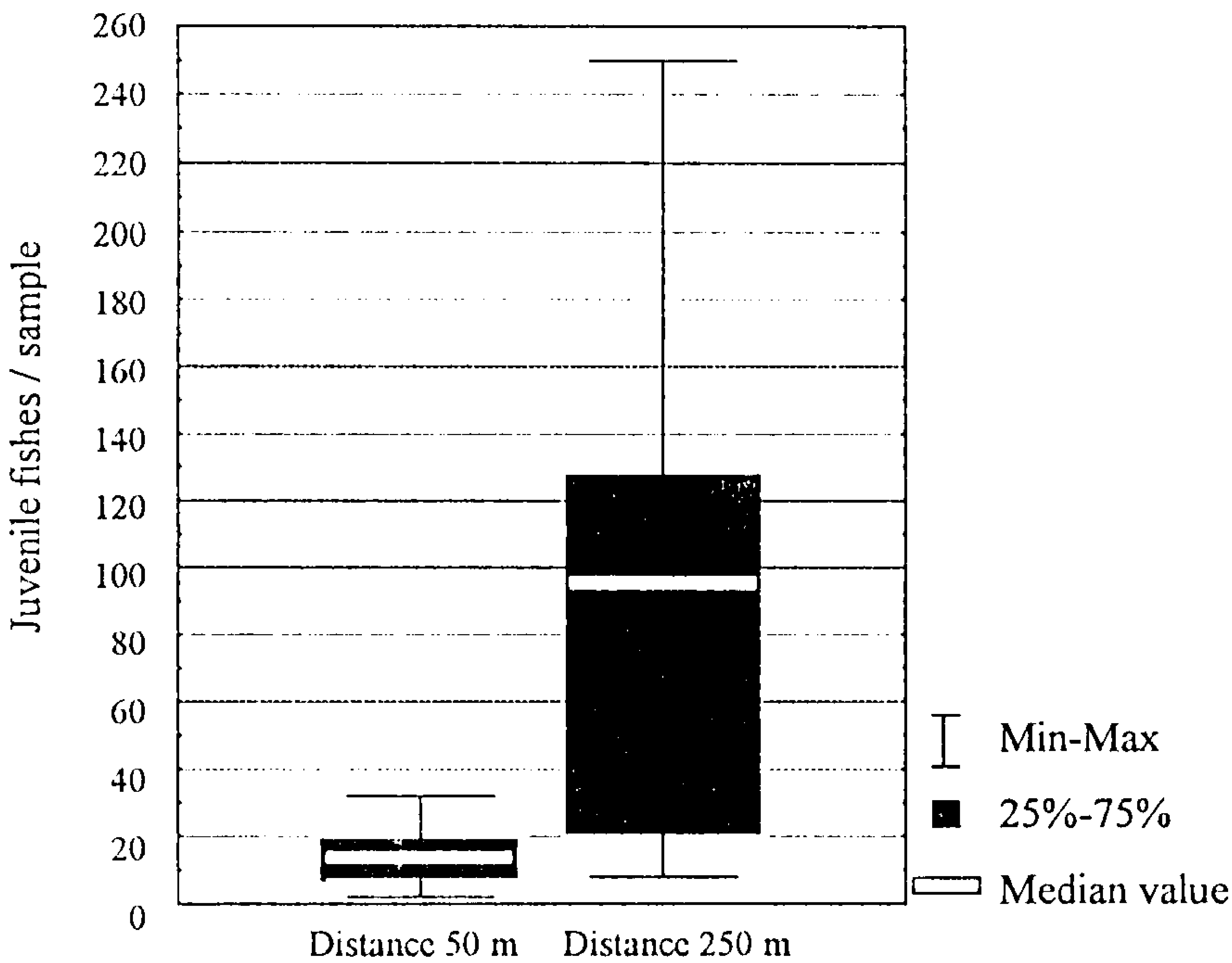

Fig. 7. - Number of juvenile fishes (≤ 50% TL max.; Lieske and Myers, 1994) in diurnal beach seine samples (Box & Whisker Plot). Significant difference tested with Kruskal-Wallis ANOVA by ranks and median test ($p < 0.001$).

Relative abundance of fishes in beach seine samples at the two stations reflects different spatial pattern (Fig. 4). Haemulidae and Pomacentridae are more abundant close to the coral reef at day. Callionymidae, Apogonidae and Lethrinidae show a higher relative diurnal abundance in a distance of 250 m from the corals. Nocturnal beach seine samples indicate that Gobiidae, Labridae, Diodontidae, Lethrinidae and Syngnathidae are more abundant in a distance of 250 m to the coral reef (Fig. 4). In contrast Apogonidae and Holocentridae occur in a higher relative abundance close to the reef at night.

Length frequencies of pooled diurnal samples indicate that 95.6% of fishes in beach seine catches and 82.0% of specimens in visual census samples are small and reach only 50% or less of their maximum size (based on Lieske and Myers, 1994) (Fig. 6). Conversely the proportion of these small, i.e., juvenile, individuals is only 56% (visual census) in the adjacent coral reef (Fig. 6). Juvenile fishes in beach seine samples show a median abundance of 95 individuals per catch in a distance of 250 m from the reef and a median abundance of 13.5 individuals per catch in a distance of 50 m during day (Fig. 7). This pattern of higher abundance far from the reef is confirmed by a Kruskal-Wallis ANOVA and median test with a significance level of $p < 0.001$. Length frequencies of Mullidae, Scorpaenidae, Lethrinidae and Plotosidae suggest that these families use the seagrass bed as a nursery area (Fig. 8). Beach seine samples of Mullidae show that 80% of all individuals belong to the size classes of 4, 5 and 6 cm (Fig. 8). More than 95% of Scorpaenidae and Lethrinidae in beach seine samples have a size of 2, 3 or 4 cm (Fig. 8). Adult individuals of Scorpaenidae and Lethrinidae are not or seldom observed in beach seine catches or by the visual census technique. 74% of Plotosidae belong to the size classes from 3 to 7 cm (Fig. 8). Juveniles of *Plotosus lineatus* occur in large schools of individuals of similar size. Adult individuals of *P. lineatus* are only observed as nocturnal visitors from the coral reef. Beach seine catches and visual census data show that juveniles of *P. lineatus* inhabit the seagrass meadow at day and night.

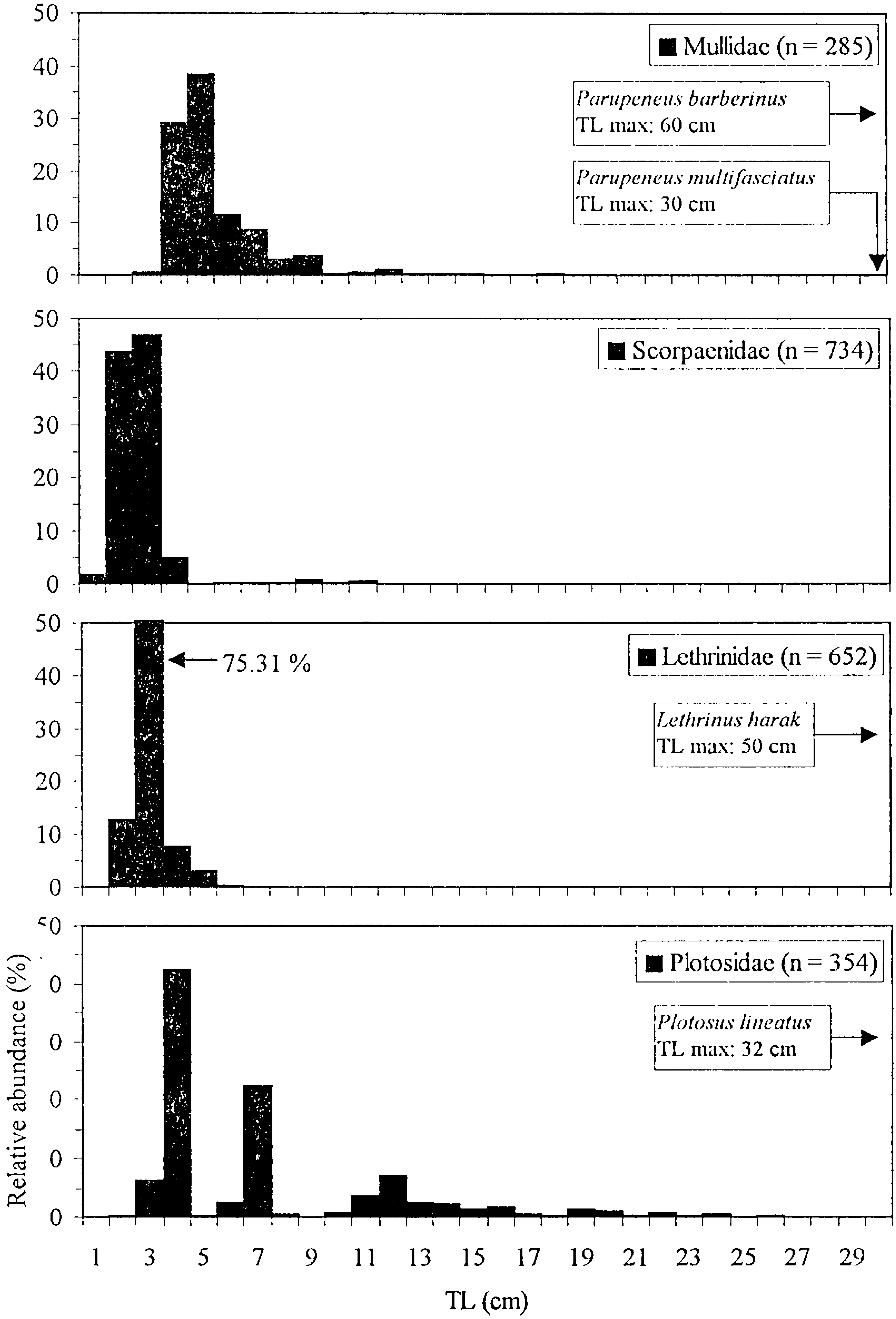

Fig. 8. - Length frequencies of Mullidae, Scorpaenidae, Lethrinidae and Plotosidae (Beach seine). Maximum length is given for the most abundant species (Lieske and Myers, 1994).

DISCUSSION

In comparison to the ichthyofauna of seagrass beds in other tropical Indo-Pacific regions, the seagrass meadow fish fauna in Malatapay is well diversified: 115 species and 42 families (Jones and Chase, 1975; Hutomo and Martosewojo, 1977; Martosewojo, 1989; Dolar, 1991; Vegara and Fortes, 1991; Sudara *et al.*, 1992). A higher number of 186 species and 48 families was observed in nocturnal beam trawl catches in a seagrass bed close to a coral reef in Bolinao, Philippines (McManus *et al.*, 1992). Fortes (1990) recorded 123 species from 51 families in Philippine seagrass meadows. On the one hand the high number of species in this study in comparison to other studies is a result of the sampling methods. Samples were taken by beach seine and visual census during the day and at night. Other studies only conducted sampling with one method during day. On the other hand the adjacent coral reef leads to an increase of species by migrating coral reef fishes. This indicates that seagrass meadows in the vicinity of coral reefs inhabit more fish species than seagrass beds without adjacent reefs. The investigations of this study show that Apogonidae, Labridae and Siganidae are the most abundant families of the seagrass meadow fish fauna. Fortes (1990) reports similar findings, but he gave more importance to Gobiidae than to Labridae. In this study, Gobiidae are less abundant.

The day active fish community is mainly composed of resident species. These species belong to the families of Labridae, Scaridae, Siganidae, Pomacentridae and Gobiidae. The night active fish community is composed of resident species, that belong to families like Bothidae, Soleidae and Callionymidae. Nocturnally migrating families such as Apogonidae, Plotosidae, Holocentridae, Diodontidae, Congridae, Muraenidae, Ophichthidae and Tetraodontidae have a high influence on the composition of the seagrass meadow fish fauna close to the reef at night. This pattern is reflected by the fact that there is no mismatch in the cluster of the nocturnal beach seine catches in a distance of 50 m to the coral reef (Fig. 2). Especially Apogonidae migrate into the seagrass meadow after sunset. This is indicated by the high relative abundance of Apogonidae close to the reef at night (Fig. 4). These nocturnal visitors migrate into the seagrass bed to forage and can feed on the abundant crustacean fauna (Weinstein and Heck, 1979; Bell and Pollard, 1989). Nocturnal feeding migrations of fishes from coral reef into adjacent seagrass beds are also described by Ogden (1980), Robblee and Zieman (1984) and Quinn and Ogden (1984). Predators such as Muraenidae, Congridae, Ophichthidae and Tetraodontidae can migrate over large distances from the reef into the seagrass bed to forage. Migrating fishes are an important vector for the export of organic matter and nutrients from seagrass beds into adjacent coral reefs (Ogden, 1980; Ogden and Gladfelter, 1983; Meyer and Schulz, 1985; Parrish, 1989; Brouns and Heijs, 1991). This foraging behaviour underlines the importance of seagrass meadows as a feeding ground for coral reef fishes.

Different fish assemblages according to the distance from the coral reef during day were evidenced. This pattern can be caused by predatory pressure of piscivore fishes from the coral reef. Large predators from the coral reef might control the abundance of smaller predators in the seagrass meadow. Therefore, the abundance of resident piscivore fishes in the seagrass meadow is limited and the predatory pressure on other resident fishes and juveniles might be reduced (Ogden, 1980; Parrish, 1989). Juvenile specimens are less abundant close to the reef than farther away from the reef. The juvenile individuals stay far away from the reef most likely to avoid predation of piscivore fishes from the coral reef. A similar pattern was observed for juvenile Acanthuridae in Caribbean seagrass meadows (Sweatman and Robertson, 1994).

Length frequencies of the fish fauna imply that mainly juvenile specimens inhabit the seagrass bed, as shown by Jones and Chase (1975), Weinstein and Heck (1979), Ogden and Gladfelter (1983) and Parrish (1989). Mullidae, Scorpaenidae, Lethrinidae and Plotosidae use the seagrass meadow as a nursery area. Fish larvae can settle down in seagrass meadows and find food and protection against predators until they are mature. As juveniles or sub adults they migrate to the coral reef. In this situation, seagrass meadows can have a important function as a "waiting room" for settlers of the coral reef fish fauna (Parrish, 1989). This supports the importance of seagrass meadows as a nursery area for coral reef fishes. For this reason seagrass beds should be more valued as a important habitat for coral reef fishes. Conservation of coral reefs is an important task in many regions of the world, but less attention is given to seagrass meadows. It is proposed that marine reserves have a function as a source of recruits for the re-colonisation of adjacent coral reefs (Man *et al.*, 1995), but beside coral reefs, seagrass meadows also can provide recruits. Therefore, reserves for the protection of coral reefs should also include the adjacent biotops, such as seagrass meadows.

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Appendix. - Ichthyofauna of the seagrass meadow in Malatapay, Negros Oriental, Philippines (* = species not identified).

Family / Species	Beach seine: Pooled day and night samples, Distance to coral reef, 50 m, n	%	250 m, n	%	Pooled stations, Day, n	%	Night, n	%	Size range TL (cm)	Visual census technique: Distance to coral reef, 50 m, n	%	250 m, n	%	Size range TL (cm)
1. Acanthuridae	12	0.1	8	0.1			20	0.2		34	0.5	23	0.7	
1. *Naso* sp.	12	0.1	8	0.1			20	0.2	3.3-5.8	34	0.5	23	0.7	4.0-7.0
2. Antennariidae	1	< 0.1					1	< 0.1						
2. *Antennarius commersoni*	1	< 0.1					1	< 0.1	3.3					
3. Apogonidae	4398	54.5	1668	23.5	791	15.6	5275	52.1		24	0.4	1202	36.2	
3. *Apogon aureus*	24	0.3	145	2			169	1.7	5.1-11.9					
4. *Apogon cyanosoma*	2185	27.1	35	0.5	21	0.4	2199	21.7	1.0-6.8					
5. *Apogon* sp.	261	3.2	33	0.5	4	< 0.1	290	2.9	1.1-6.3					
6. Apogonidae*	1551	19.2	1214	17.1	513	10.2	2252	22.2	0.9-18.5	24	0.4	1202	36.2	2.0
7. *Cheilodipterus quinquelineatus*	377	4.7	241	3.4	253	5	365	3.6	0.6-11.3					
4. Belonidae										1	< 0.1			
8. *Tylosurus crocodilus crocodilus*										1	< 0.1			50.0
5. Blenniidae			1	< 0.1			1	< 0.1		5	< 0.1			
9. *Meiacanthus grammistes*										5	< 0.1			8.0-10.0
10. Nemophini*			1	< 0.1			1	< 0.1	4.2					
6. Bothidae	224	2.7	394	5.6	268	5.3	350	3.4		1	< 0.1	1	< 0.1	
11. Bothidae*	204	2.5	387	5.5	249	4.9	342	3.4	1.0-7.8					
12. *Bothus pantherinus*	20	0.2	7	0.1	19	0.4	8	< 0.1	4.2-18.1	1	< 0.1	1	< 0.1	
7. Caesionidae	1	< 0.1					1	< 0.1				4	0.1	
13. *Caesio* sp.												4	0.1	25.0
14. *Pterocaesio pisang*	1	< 0.1					1	< 0.1	4.8					
8. Chaetodontidae												3	0.1	
15. *Chaetodon* sp.												3	0.1	4.0
9. Callionymidae	10	0.1	13	0.2	9	0.2	14	0.1						
16. Callionymidae*	10	0.1	12	0.2	8	0.2	14	0.1	1.8-13.7					
17. *Dactylopus dactylopus*			1	< 0.1	1	< 0.1			17					
10. Carangidae			1	< 0.1	1	< 0.1								
18. *Carangoides* sp.			1	< 0.1	1	< 0.1			9.6					

11. Carapidae	1	< 0.1					1	< 0.1						
19. Carapidae*	1	< 0.1					1	< 0.1	10.4					
12. Congridae	12	< 0.1	7	< 0.1			19	0.1						
20. *Conger cinereus*	7	< 0.1	5	< 0.1			12	0.1	8.8-26.3					
21. *Conger* sp.	1	< 0.1					1	< 0.1	19.2					
22. Congridae*	4	< 0.1	2	< 0.1			6	< 0.1	1.8-24.1					
13. Cynoglossidae	2	< 0.1	3	< 0.1	1	< 0.1	4	< 0.1						
23. Cynoglossidae*	2	< 0.1	3	< 0.1	1	< 0.1	4	< 0.1	7.4-14.9					
14. Dasyatidae			2	< 0.1	2	< 0.1								
24. *Taeniura lymma*			2	< 0.1	2	< 0.1			39.0-40.5					
15. Diodontidae	1	< 0.1	37	0.5	11	0.2	27	0.3				1	< 0.1	
25. *Diodon holocanthus*	1	< 0.1	37	0.5	11	0.2	27	0.3	10.4-21.5			1	< 0.1	
16. Fistulariidae			1	< 0.1			1	< 0.1						
26. *Fistularia commersonii*			1	< 0.1			1	< 0.1	14.2					
17. Gobiidae	61	0.6	237	3.3	75	1.4	223	2.2		15	0.2	32	1.0	
27. *Amblygobius phalaena*			1	< 0.1	1	< 0.1			5.8					
28. *Amblygobius sphynx*	6	< 0.1	74	1	32	0.6	48	0.5	1.1-7.3					
29. Gobiidae*	29	0.4	161	2.3	17	0.3	173	1.7	1.0-6.4	8	0.1	26	0.8	1.0-7.0
30. *Valenciennea longipinnis*	1	< 0.1			1	< 0.1			5.5					
31. *Valenciennea puellaris*	7	< 0.1			6	0.1	1	< 0.1	6.2-12.2	5	0.1	4	0.1	5.0-8.0
32. *Valenciennea sexguttata*	18	0.2	1	< 0.1	18	0.4	1	< 0.1	2.2-7.9	2	< 0.1	2	< 0.1	8.0-10.0
18. Haemulidae	7	< 0.1	2	< 0.1	6	0.1	3	< 0.1						
33. *Plectorhinchus diagrammus*	7	< 0.1	2	< 0.1	6	0.1	3	< 0.1	1.6-4.4					
19. Holocentridae	17	2.4					17	0.2						
34. Holocentridae*	17	2.4					17	0.2	2.7-7.9					
20. Labridae	1053	12.8	2297	32.1	2524	49.8	826	8.2		1056	16.8	403	12.1	
35. *Cheilinus bimaculatus*	411	5.1	1861	26.2	1514	30.1	758	7.5	0.7-12.9	65	1.0	74	2.2	5.0-15.0
36. *Cheilinus trilobatus*	16	0.2	51	0.7	37	0.7	30	0.3	2.5-10.1			4	0.1	10.0-12.0
37. *Cheilio inermis*	277	3.4	208	2.9	448	8.9	37	0.4	1.2-21.6	180	2.9	121	3.6	10.0-35.0
38. *Halichoeres chloropterus*	82	1	75	1.1	157	3.1			1.1-8.4	101	1.6	103	3.1	1.0-6.0
39. *Halichoeres interrupta*			1	< 0.1	1	< 0.1			3.8					
40. *Halichoeres margaritaceus*	1	< 0.1	6	< 0.1	1	< 0.1			3.8					
41. *Halichoeres miniatus*	1	< 0.1			1	< 0.1			2.7					
42. *Halichoeres scapularis*	49	0.6			55	1.1			1.1-4.3	182	2.9	77	2.3	3.0-20.0
43. *Halichoeres* sp.	32	0.4	15	0.2	47	0.9			1.5-8			3	0.1	5.0-8.0
44. *Halichoeres zeylonicus*	6	< 0.1	2	< 0.1	7	0.1	1	< 0.1	2.1-11.5	1	< 0.1			15.0
45. Labridae*	21	0.3	16	0.2	37	0.7			1.2-7.1	188	3.0	17	0.5	3.0-10.0
46. *Novaculichtys macrolepidotus*	59	0.7	29	0.4	88	1.7			5.5-16.2	4	< 0.1	4	0.1	10.0-12.0

Appendix 1.- Continued.

Family	Beach seine									Visual census technique				
	Pooled day and night samples				Pooled stations				Size					Size
	Distance to coral reef									Distance to coral reef				
	50 m		250 m		Day		Night		range	50 m		250 m		range
Species	n	%	n	%	n	%	n	%	TL (cm)	n	%	n	%	TL (cm)
47. *Pteragogus flagellifer*			3	< 0.1	3	< 0.1			7.3-8.7					
48. *Stethojulis interrupta*	89	1.1	30	0.4	119	2.4			1.0-11.9					
49. *Thalassoma lunare*	7	< 0.1			7	0.1			8.6-17.3	335	5.3			10.0-15.0
50. *Xyrichtys pentadactylus*	2	< 0.1			2	< 0.1			15.2-15.7					
21. Lethrinidae	69	0.9	583	8.2	399	7.9	253	2.5		32	0.5	5	0.2	
51. Lethrinidae*	69	0.9	582	8.2	398	7.9	253	2.5	1.1-6.8					
52. *Lethrinus genivittatus*			1	< 0.1	1	< 0.1			9.5					
53. *Lethrinus harak*										32	0.5	5	0.2	18.0-40.0
22. Lutjanidae	2	< 0.1	7	< 0.1	2	< 0.1	7	< 0.1						
54. Lutjanidae*			2	< 0.1			2	< 0.1	1.9-2.5	1	< 0.1			
55. *Lutjanus fluviflamma*	2	< 0.1	4	< 0.1	2	< 0.1	4	< 0.1	2.2-19.7	1	< 0.1			
56. *Lutjanus kasmira*			1	< 0.1			1	< 0.1	9.3					
23. Monacanthidae	3	< 0.1	7	0.1	5	< 0.1	5	< 0.1		5	0.1	1	< 0.1	
57. Monacanthidae*	3	< 0.1	7	0.1	5	< 0.1	5	< 0.1	1.2-12.4	5	0.1	1	< 0.1	4.0
24. Mugilidae												2	< 0.1	
58. *Crenimugil crenilabis*													2	< 0.1
25. Mullidae	60	0.6	224	3.2	213	4.1	71	0.4		42	0.7	134	4.0	
59. Mullidae*										19	0.3	9	0.3	4.0-6.0
60. *Mulloidichthys flavolineatus*	10	0.1					10	< 0.1	7.7-8.8					
61. *Parupeneus barberinoides*	16	0.2	23	0.3	33	0.7	6	< 0.1	3.3-8.2					
62. *Parupeneus barberinus*	28	0.3	169	2.4	163	3.2	34	0.3	3.3-7.8			79	2.4	4.0-10.0
63. *Parupeneus cyclostomus*	1	< 0.1	20	0.3	7	0.1	14	0.1	6.5-14.2					
64. *Parupeneus indicus*			1	< 0.1			1	< 0.1	5.8	6	0.1	29	0.9	7.0-35.0
65. *Parupeneus multifasciatus*	3	< 0.1			3	< 0.1			5.4-7.6	15	0.2	2	< 0.1	4.0
66. *Upeneus tragula*	2	< 0.1	11	0.2	7	0.1	6	< 0.1	2.9-17.1	2	< 0.1	15	0.5	4.0-18.0
26. Muraenidae	2	< 0.1	5	< 0.1			7	< 0.1		3	< 0.1	1	< 0.1	
67. *Enchelynassa canina*			2	< 0.1			2	< 0.1	26.1-35.5					
68. *Gymnothorax chilospilus*	1	< 0.1	2	< 0.1			3	< 0.1	23.4-30.0					
69. *Gymnothorax pseudothyrsoideus*	1	< 0.1	1	< 0.1			2	< 0.1	34.0-34.6					
70. Muraenidae*										3	< 0.1	1	< 0.1	20.0-40.0

27. Nemipteridae	5	< 0.1	19	0.2	9	0.1	15	0.1						
71. Nemipteridae*	1	< 0.1	5	< 0.1	6	0.1			2.0-2.1					
72. *Scolopsis affinis*			14	0.2	1	< 0.1	13	0.1	9.3-13.1					
73. *Scolopsis bilineatus*	3	< 0.1			2	< 0.1	1	< 0.1	3.0-7.2					
74. *Scolopsis* sp.	1	< 0.1					1	< 0.1	7.8					
28. Ophichthidae	3	< 0.1	5	< 0.1	1	< 0.1	7	< 0.1						
75. *Leiuranus semicinctus*			1	< 0.1			1	< 0.1	50.5					
76. *Muraenichtys macropterus*	3	< 0.1	4	< 0.1	1	< 0.1	6	< 0.1	9.6-18.4					
29. Ostraciidae			2	< 0.1	1	< 0.1	1	< 0.1						
77. *Ostracion cubicus*			2	< 0.1	1	< 0.1	1	< 0.1	1.2-1.9					
30. Pinguipedidae	5	< 0.1	1	< 0.1	3	< 0.1	3	< 0.1		19	0.3	4	0.1	
78. *Parapercis cylindrica*	5	< 0.1	1	< 0.1	3	< 0.1	3	< 0.1	2.7-10.7					
79. Parapercis sp.										19	0.3	4	0.1	5.0-12.0
31. Platycephalidae	6	< 0.1	9	< 0.1	3	< 0.1	12	< 0.1						
80. Platycephalidae*	3	< 0.1	6	< 0.1	1	< 0.1	8	< 0.1	2.1-12.6					
81. *Thysanophrys arenicola*	3	< 0.1	3	< 0.1	2	< 0.1	4	< 0.1	4.1-10.5					
32. Plotosidae	1276	15.8	227	3.2			1503	14.8		1060	17.0	501	15.1	
82. *Plotosus lineatus*	1276	15.8	227	3.2			1503	14.8	1.3-25.5	1060	17.0	501	15.1	2.0
33. Pomacentridae	72	0.8	24	0.2	90	1.7	6			3008	47.9	163	4.9	
83. *Abudefduf vaigiensis*			15	0.2	13	0.3	2	< 0.1	3.0-5.6					
84. *Amphiprion clarki*	i2	< 0.1	2	< 0.1	3	< 0.1	1	< 0.1	2.6-7.5	61	0.9	3	0.1	3.0-12.0
85. *Amphiprion polymnus*			1	< 0.1	1	< 0.1			6.9					
86. *Amphiprion* sp.										8	0.1	2	0.1	2.0-10.0
87. *Chromis* sp.										1	< 0.1			8.0
88. *Dascyllus* sp.	1	< 0.1			1	< 0.1			10.1				1	< 0.1
89. *Dascyllus trimaculatus*	6	< 0.1	2	< 0.1	6	0.1	2	< 0.1	1.7-10.6	19	0.3			2.0-5.0
90. *Pomacentrus coelestis*	63	0.8	4	< 0.1	66	1.3	1	< 0.1	1.5-7.6	2809	44.8	50	1.5	2.0-5.0
91. Pomacentridae*										110	1.8	107	3.2	1.0-6.0
34. Scaridae	232	2.8	240	3.3	365	7.1	107	1		45	0.7	52	1.6	
92. *Calotomus spinidens*	218	2.7	237	3.3	350	6.9	105	1	0.9-15.9					
93. *Leptoscarus vaigiensis*	10	0.1	2	< 0.1	10	0.2	2	< 0.1	1.9-18.5					
94. Scaridae*	4	< 0.1	1	< 0.1	5	< 0.1			1.5-2.4	45	0.7	52	1.6	5.0-25.0
35. Scorpaenidae	328	4	509	7.1	22	0.3	815	8						
95. *Ablabys taenianotus*	8	0.1	7	0.1	4	< 0.1	11	0.1	3.1-9.7					
96. *Dendrochirus brachypterus*			2	< 0.1	2	< 0.1			10.6-10.7					
97. *Dendrochirus zebra*			2	< 0.1	2	< 0.1			8.5-10.5					
98. *Inimicus caledonicus*			1	< 0.1			1	< 0.1	9.6					

Appendix 1.- Continued (2).

Family	Beach seine									Visual census technique				
	Pooled day and night samples				Pooled stations				Size range	Distance to coral reef				Size range
	Distance to coral reef				Day		Night			50 m		250 m		
	50 m		250 m											
Species	n	%	n	%	n	%	n	%	TL (cm)	n	%	n	%	TL (cm)
99. *Paracentropogon longispinis*	1	< 0.1					1	< 0.1	2.7					
100. *Parascorpaena mossambica*			1	< 0.1			1	< 0.1	9.5					
101. *Scorpaenodes* sp.	319	3.9	496	7	14	0.3	801	7.9	0.9-11.8					
36. Siganidae	68	0.7	399	5.7	167	3.3	300	2.9		917	14.6	790	23.7	
102. *Siganus canaliculatus*	6	< 0.1	12	0.2	2	< 0.1	16	0.2	11.0-17.0					
103. *Siganus* sp.	55	0.7	387	5.5	165	3.3	277	2.7	0.8-4.7	917	14.6	790	23.7	10.0-20.0
104. *Siganus spinus*	7	< 0.1					7	< 0.1	10.5-15.0					
37. Sillaginidae	1	< 0.1					1	< 0.1						
105. *Sillago sihama*	1	< 0.1					1	< 0.1	9.8					
38. Soleidae	22	0.2	12	0.2	4		30	2.5						
106. *Pardachirus pavoninus*	6	< 0.1	1	< 0.1	2	< 0.1	5	< 0.1	4.2-14.5					
107. Soleidae*	16	0.2	11	0.2	2	< 0.1	25	2.5	1.9-11.0					
39. Sphyraenidae	51	0.6	104	1.5	6	0.1	149	1.5						
108. *Sphyraena flavicauda*	42	0.5	97	1.4	6	0.1	133	1.3	2.7-11.2					
109. *Sphyraena* sp.	9	0.1	7	0.1			16	0.2	4.0-5.5					
40. Syngnathidae	10	< 0.1			6	< 0.1	4	< 0.1						
110. *Doryrhamphus dactyliophorus*	3	< 0.1			2	< 0.1	1	< 0.1	7.1-35.9					
111. *Micrognathus vittatus*	1	< 0.1					1	< 0.1	2.5					
112. Syngnathidae sp.	3	< 0.1			1	< 0.1	2	< 0.1	15.5-19.6					
113. *Trachyramphus bicoarctatus*	3	< 0.1			3	< 0.1			7.5-33.4					
41. Synodontidae	75	0.8	32	0.5	41	0.6	66	0.5		3	< 0.1			
114. *Saurida gracilis*	24	0.3	13	0.2	17	0.3	20	0.2	3.2-16.5	3	< 0.1			15.0-18.0
115. Synodontidae*	41	0.5	12	0.2	18	0.3	35	0.3	1.2-4.0					
116. *Synodus dermatogenys*	4	< 0.1			3	< 0.1	1	< 0.1	3.0-4.1					
117. *Trachinocephalus myops*	6	< 0.1	7	0.1	3	< 0.1	10	< 0.1	2.5-9.9					
42. Tetraodontidae	3	< 0.1	2	< 0.1	1	< 0.1	4	< 0.1				1	< 0.1	
118. *Arothron* sp.	1	< 0.1					1	< 0.1	31.2			1	< 0.1	30.0
119. *Arothron stellatus*		1	< 0.1			1	< 0.1	56.5						
120. *Canthigaster bennetti*	2	< 0.1			1	< 0.1	1	< 0.1	3.3-7.7					
121. Tetraodontidae*			1	< 0.1			1	< 0.1	2.4					
Total	8,087	100	7,078	100	5,026	100	10,139	100		6,276	100.0	3,324	100.0	