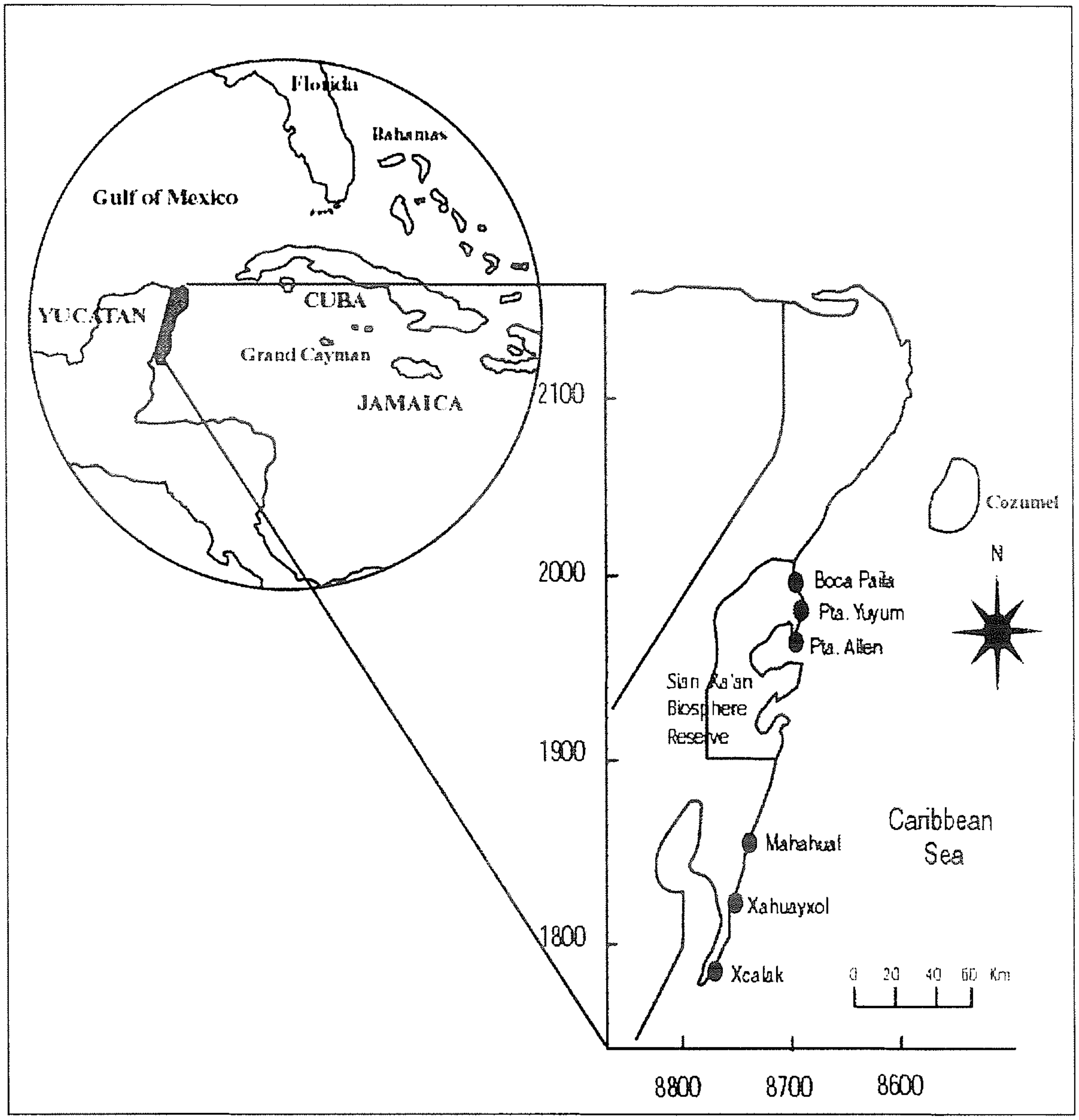

Figure 1. AGRRA survey sites (boldface) in central-southern Quintana Roo, México.

CONDITION OF CORAL REEF ECOSYSTEMS IN CENTRAL-SOUTHERN QUINTANA ROO (PART 3: JUVENILE REEF FISHES)

BY

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ABSTRACT

The spatial patterns of coral reef fish recruits were assessed using a visual census method at three scales (subreefs, reefs, and areas) between June and August, 1999 in the spur-and-groove habitat of six fore reefs in the Mexican Caribbean. Six thousand three hundred twenty-seven fish recruits belonging to 54 species in 30 genera and 18 families were counted. Slight differences were found in composition and density of all species at all three spatial scales. A multiple regression analysis indicated statistically significant relationships with recruit density that were positive for mean diameter and negative for the live/dead ratio of "large" (≥25 cm diameter) stony corals. Recruit density may depend largely on the intrinsic behavior of each species in direct relation to food and refuge availability, rather than on live coral coverage.

INTRODUCTION

The fringing coral reefs of the Mexican Caribbean form the northernmost part of the Mesoamerican Barrier Reef. They extend 350 km along the eastern coast of Quintana Roo state from the northeasterly corner of the Yucatán Peninsula to its southern frontier with Belize (Fig. 1). The Sian Ka'an Biosphere Reserve is located in the central-eastern portion of Quintana Roo from just south of Tulum (20° 06' N, the northern boundary of Sian Ka'an), to Punta Punticub (19° 05' N). The reserve consists of 528,147 hectares with limited access and includes Ascensión and Espíritu Santo Bays. About 120,000 hectares are coastal and marine environments encompassing the coral reef zone (Gutiérrez-Carbonel et al., 1993).

Six reefs were sampled as part of the present study, three within the Sian Ka'an Biosphere Reserve and three outside the Reserve in the southern portion of the Mexican Caribbean (Fig. 1). Two of the reserve's reefs are remote from population centers (Boca

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Paila, Punta Yuyum), which has allowed their natural conditions to be largely conserved. The third, Punta Allen, is situated near the settlement of Rojo Gómez where the principal activity is a small-scale lobster fishery. Two of the reefs outside of the reserve (Mahahual, Xcalak) are located near human settlements where small-scale fishing is the predominant activity although most of the fleet's capture is focused on the open sea or at Chinchorro Bank rather than in the coastal reef zone. The reef at Xahuayxol has been relatively undisturbed anthropogenically. The principal fishing methods used are fixed traps, trotlines, gill nets and harpoons and these are mostly directed toward capture of commercially important species such as grouper (serranids), barracuda (sphyranids), snapper (lutjanids) and grunts (haemulids).

Relatively little research has been done on the coral reefs in the Mexican Caribbean and even less on its reef fishes. Earlier studies, predominantly focused on adult fish community structure, have been summarized by Arias-González et al. (1997) and Salazar et al. (1997). Recently Castro (1998) has characterized the fish community structure of Mahahual Reef. Núñez-Lara (1998) and Núñez-Lara and Arias-González (1998) have demonstrated the importance of environmental factors, particularly topographic complexity, in determining reef fish community structure. Arias-González (1998) has created trophic models for a protected and an unprotected zone, finding important differences reflected in fish biomass. Díaz-Ruiz et al. (1999) presented evidence that variations in species diversity and trophic structure are associated with sequential habitat use during the life cycle.

Recruitment is widely considered a key structuring process in reef fish communities (Doherty and Williams, 1988; Doherty and Fowler, 1994). Previous studies in the Western Atlantic have focused on the factors that regulate temporal and spatial variability in recruitment such as predation, refuge availability, and habitat use (Shulman, 1985a, 1985b; Shultz and Cowen, 1994; Booth and Beretta, 1994; Caselle and Warner, 1996). Enhanced understanding of natural fluctuations in recruitment and its relationship to coral reef conditions would allow more effective management of fishery resources. This study is the first assessment of coral reef fish recruitment patterns at different spatial scales in the Mexican Caribbean. Relationships between recruitment and descriptors of benthic reef condition are also examined.

METHODS

Reef fish recruitment patterns were visually assessed between June 25 and August 31, 1999 on three spatial scales: area, reef and subreef. The central and southern areas of Quintana Roo have coastlines that are approximately 100 km long. Each of these areas was represented by three, strategically chosen reefs (see Ruiz et al., this volume), which were separated from one another by about 25-30 km. Every reef was partitioned into three representative subreefs at approximately 1 km intervals. Ten belt transects, each 30 m long by 1 m wide, were swum parallel to the coast at a depth of 12 m in the spur-and-groove habitat of the fore-reef zone by one diver (González-Salas) in every subreef. The spacing between adjacent transects was about 50 m. To assess the diurnal community of juvenile reef fishes, all surveys were made between 09:00 and 14:00 hours. Recruits were identified to species, or to the lowest possible taxonomic level. Their size was estimated with a T-bar. Fish identifications were based on the descriptions of Randall (1983), Lindeman (1986), Humman (1994), and Lieske and Myers (1995).

Recruitment patterns were analyzed on the three spatial scales. Multiple regression analysis was used to estimate the relationship between juvenile density and benthic variables [total live stony coral cover; total, old, and recent partial-colony mortality, live/dead ratio, mean diameter, and percent bleached or diseased colonies for "large" (≥25 cm diameter) stony corals; relative abundance of macroalgae and turf], which were measured in the same sites by Ruiz et al. (this volume). To evaluate the affinity of the sampling stations, a multivariate classification analysis based on the density of the fish species was made using the Bray-Curtis distance index (Bray and Curtis, 1957), complemented by the Unweighted Pair Grouping Method Average (UPGMA) cluster method. The Atlantic and Gulf Rapid Reef Assessment (AGRRA) fishes constitute a subset of the "all species" data: in this paper, "serranids" are species of *Epinephelus* (excluding *E. cruentatus* and *E. fulvus*, here considered to be *Cephalopholis cruentata* and *C. fulva*, respectively) and *Mycteroperca*.

RESULTS

A total of 54 species of reef fish recruits belonging to 30 different genera and 18 families were identified in the surveys. No difference was noted in species richness at the largest spatial scale (Fig. 2), but the central area had reefs with both the highest (Boca Paila) and lowest (Punta Allen) numbers of species (Table 1). A total of 6,327 reef fish recruits were counted: 3,337 in the central area and 2,990 in the southern area. Hence, the "all species" recruit density was somewhat higher in the central area (Fig. 3). The highest densities, found in Boca Paila (central area) and Xcalak (southern area), were about twice that of the lowest in Xahuayxol (southern area). The mean "all species" recruit density overall was 117 individuals/100m^2.

The 25 most frequently sighted species (Table 2) were a mixture of herbivores (*Stegastes*, *Sparisoma*, *Acanthurus*, *Scarus*) and carnivores that feed primarily on the benthos (*e.g.*, *Halichoeres*, many other genera).

Overall, recruits of the AGRRA herbivores (scarids, acanthurids) were more abundant than the AGRRA carnivores (lutjanids>haemulids>serranids as defined above) (Table 3). Mean densities of parrotfish (scarid) recruits were highest in the two most northerly reefs of the central area (Boca Paila, Punta Yuyum) and in Mahahual, the most northerly reef of the southern area. Surgeonfish (acanthurid) recruits were most common in the most southerly reef (Xcalak) and least abundant in Mahahual.

The multiple regression analysis indicated that the mean diameter and live/dead ratio of the ≥25 cm in diameter stony corals together explained more than 60% of the variability in recruit density. The relationship with mean coral diameter was positive (r^2= 0.276, p = 0.02), whereas that with the live/dead ratio was negative (r^2= 0.379, $p< 0.05$) (Fig. 4). The remaining variables had no significant relationship with recruit density.

A numerical classification analysis in Q mode identified five groups of fish recruits (Fig. 5). The first includes four subreefs from the southern area and one from the central area. The second and fifth groups are restricted to the central area whereas the third and fourth are located in the southern area.

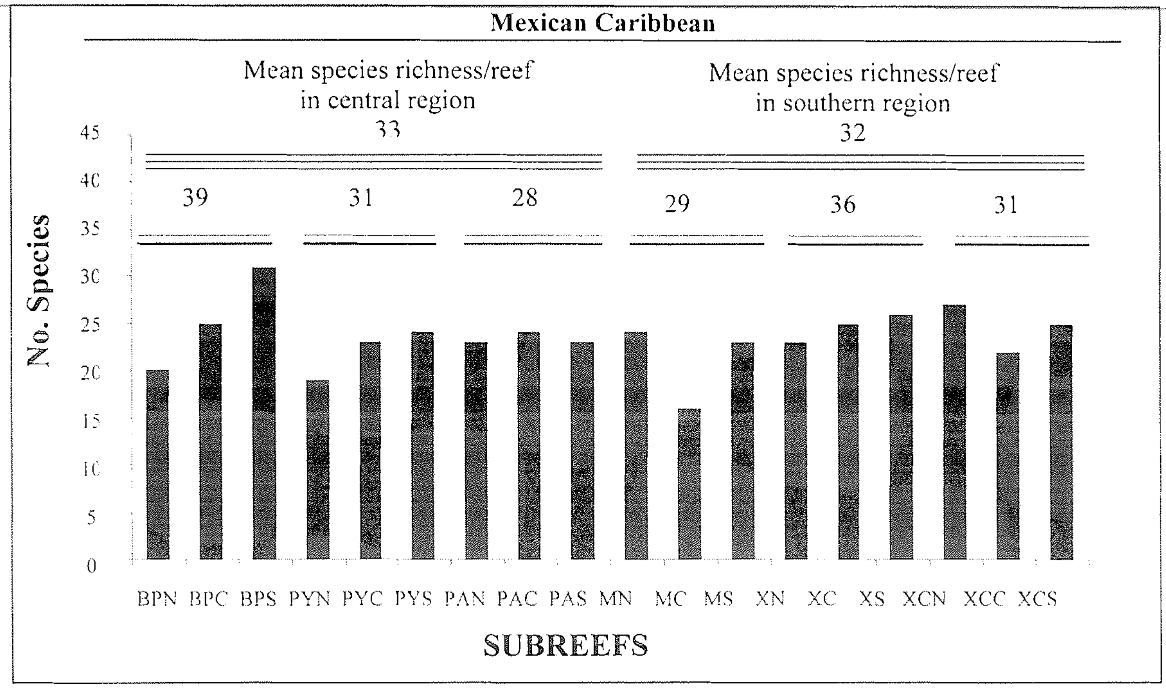

Figure 2. Species richness of all species of juvenile coral reef fishes, by subreef in central-southern Quintana Roo, México. See Table 1 for site codes.

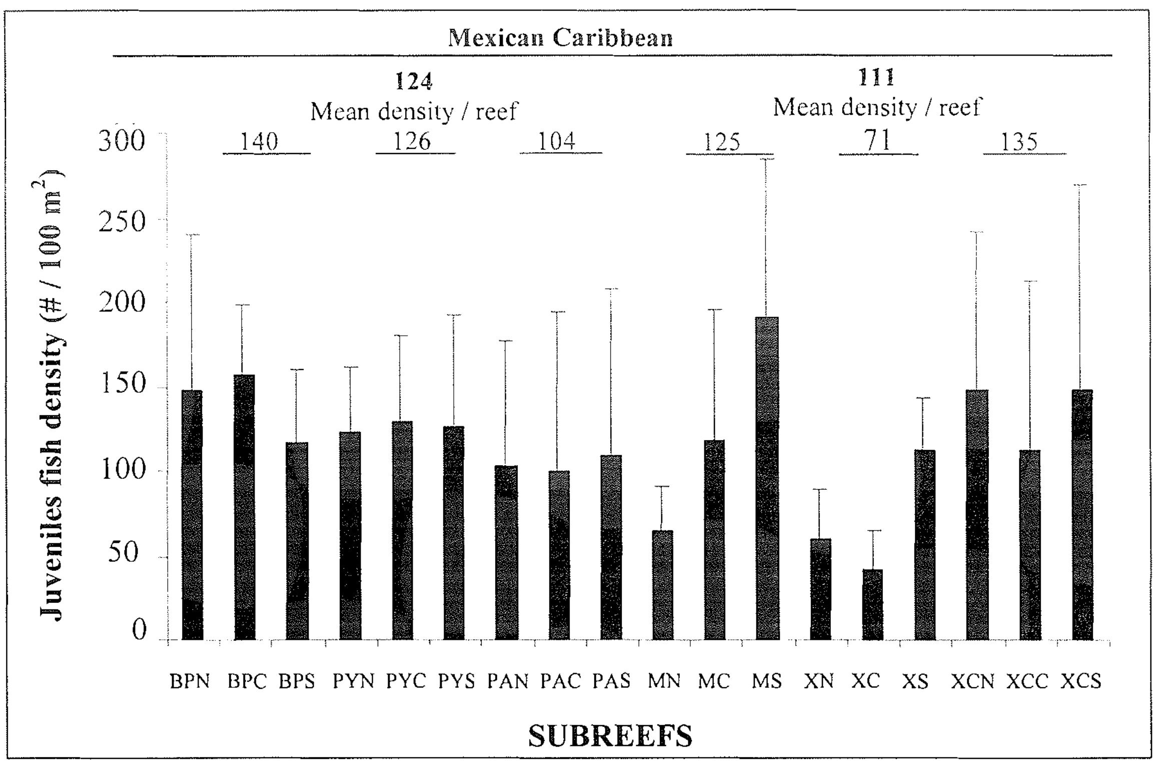

Figure 3. Mean density (no. individuals/100 m^2) of all species of juvenile coral reef fishess by subreef in central-southern Quintana Roo, México. See Table 1 for site codes.

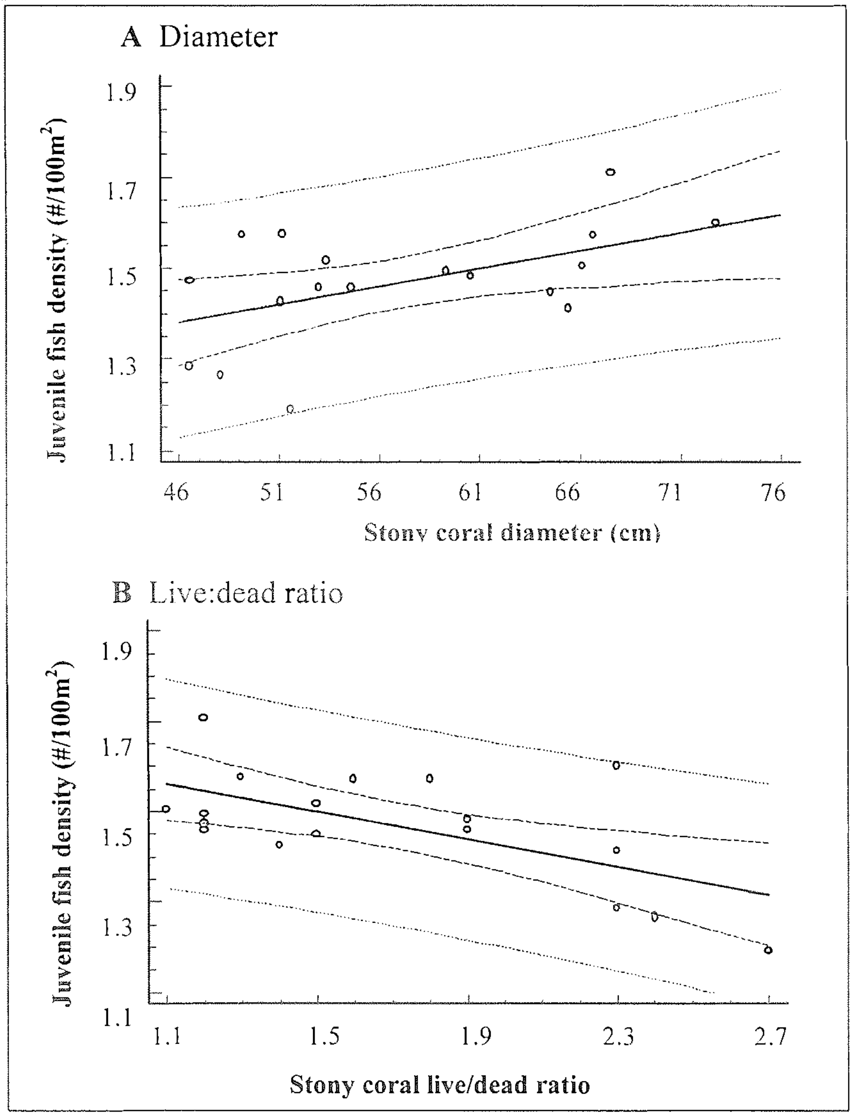

Figure 4. Regression plot between mean juvenile reef fish density (no. individuals/100 m^2) and (**A**) mean stony coral diameter (y=1.041+0.00795374x, r^2=0.276, f(1,16)=6.13, p=.002) and (**B**) mean stony coral live/dead ratio (y=1.73079-0.15325x, r^2=0.379, f(1,16)=9.79, p=.006), by subreef in central-southern Quintana Roo, México.

DISCUSSION

The similarity in the species richness of recruits in the central and southern areas is probably attributable in part to the great similarity in their reef structures although large-scale physical processes (such as current patterns) should also be taken into account. Much of the subreef- and reef-scale variability in reef fish recruitment could be related to local, coastal environmental factors. For example, the relatively high values found off Boca Baila (northern area) and off Xahuayxol and Xcalak (southern area) were all in reefs that are close to lagoons or bays that may serve as sources of recruits.

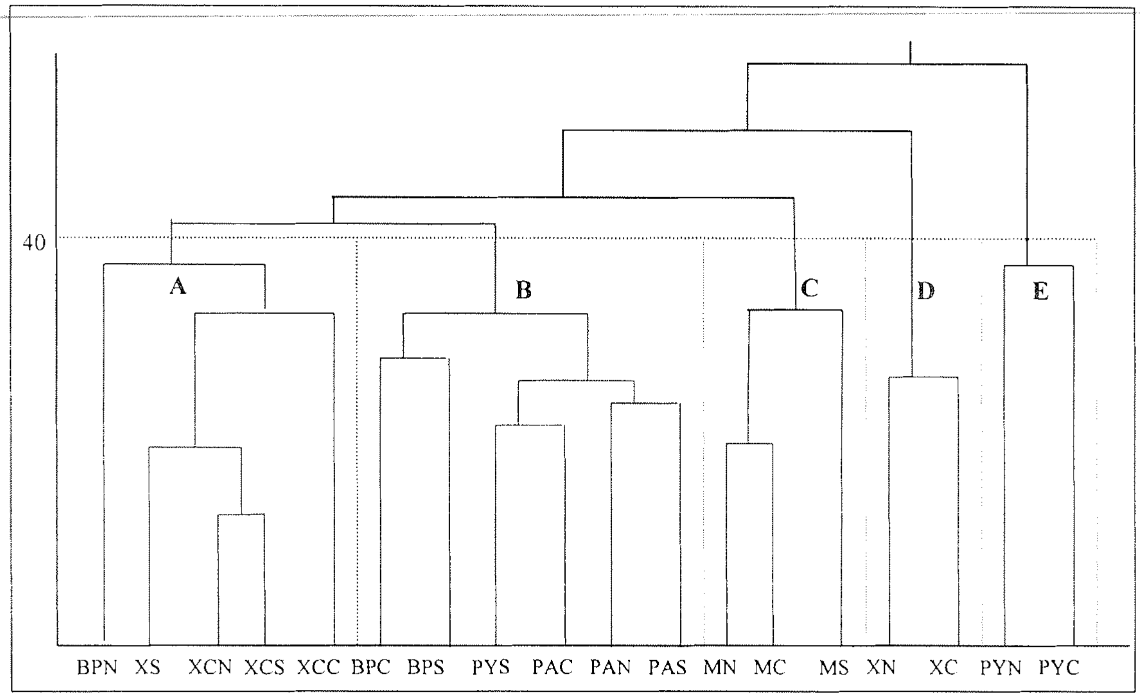

Figure 5. Hierarchical classification analysis of the juvenile fish transect data by subreef in central-southern Quintana Roo, México. See Table 1 for site codes. Labels A-E represent groups of sites with similar juvenile fish community structure.

Whereas adult herbivores (parrotfishes and surgeonfishes) were relatively abundant in the more heavily fished reefs where their natural predators are less common (Nuñez-Lara et al., this volume), the mean density of their recruits showed relatively little between-reef variation (Table 3). The relative paucity of juvenile snappers and grunts compared to adult densities found by Nuñez-Lara et al. (this volume) is probably related to the strong association of the juveniles with lagoonal systems, particularly in Boca Paila, Punta Yuyum and Punta Allen.

Recruitment variation at any of the three scales is likely to be influenced by one or more of the following factors: differential larval availability; differential settlement during habitat selection; mortality differences in early, post-settlement stages; or post-recruitment movement towards different preferred habitats (Caselle, 1996). The positive relationship between recruit density and stony coral diameter suggests that the survival of reef fish recruits is enhanced by the greater structural complexity of large corals. Indeed, Nemeth (1998) has recently documented the positive effects of hole and crevice density on recruit abundance. The overall negative relationship with the live/dead coral ratio, as previously found in St. Croix, U.S. Virgin Islands (Booth and Beretta, 1994; Caselle and Warner, 1996) is an indication that recruit density is largely independent of the condition of these stony corals. In other words, the dominant factors affecting reef fish recruitment apparently are not associated with the benthos condition indicators recorded by Ruiz et al. (this volume) but rather with larval input and behavior, as well as the availability of refuges and food. If the scales at which recruitment is being carried out are smaller than those employed in this study, it will be necessary to measure other variables, such as refuge type, or the heterogeneity, size and density of refuges in reef substrata.

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Table 1. Site information for AGRRA juvenile fish surveys in central-southern Quintana Roo, México

Site name	Site code	Reef type	Latitude (° ' " N)	Longitude (° ' " W)	Survey Date	Depth (m)	≥25 cm stony corals (#/10 m)[1]	% live stony coral cover (mean ± sd)[1]	30 m fish transects (#)	Species in transects (#)	
										"AGRRA"[2]	Total
Central											
Boca Paila North	BPN	Fringing	20 06 51	87 27 23	Aug. 30 99	12	6	15.5 ± 4.5	10	9	20
Boca Paila Center	BPC	Fringing	20 06 21	87 27 34	Aug. 31 99	12	6	19.0 ± 9.5	10	9	25
Boca Paila South	BPS	Fringing	20 05 51	87 27 47	Aug. 31 99	12	2	8.5 ± 2.5	10	11	31
Punta Yuyum North	PYN	Fringing	19 58 30	87 27 10	Aug. 27 99	12	4.5	10.5 ± 5.5	10	7	19
Punta Yuyum Center	PYC	Fringing	19 58 00	87 27 06	Aug. 26 99	12	4	12.5 ± 6.0	10	10	23
Punta Yuyum South	PYS	Fringing	19 57 30	87 26 52	Aug. 25 99	12	4.5	10.5 ± 6.0	10	8	24
Punta Allen North	PAN	Fringing	19 50 30	87 26 15	Aug. 20 99	12	4.5	11.5 ± 3.5	10	8	23
Punta Allen Center	PAC	Fringing	19 50 00	87 26 36	Aug. 21 99	12	4.5	14.5 ± 7.5	10	9	24
Punta Allen South	PAS	Fringing	19 49 30	87 26 52	Aug. 22 99	12	3.5	10.5 ± 4.5	10	7	23
Southern											
Mahahual North	MN	Fringing	18 43 24	87 41 56	June 27 99	12	5	17.0 ± 7.0	10	12	24
Mahahual Center	MC	Fringing	18 43 01	87 42 09	June 26 99	12	4.5	17.0 ± 6.0	10	6	16
Mahahual South	MS	Fringing	18 42 30	87 42 20	June 25 99	12	6	16.5 ± 5.5	10	8	23
Xahuayxol North	XN	Fringing	18 30 55	87 45 02	July 20 99	12	3.5	11.5 ± 3.0	10	10	23
Xahuayxol Center	XC	Fringing	18 30 25	87 45 13	July 21 99	12	2.5	12.0 ± 5.5	10	11	25
Xahuayxol South	XS	Fringing	18 29 55	87 45 22	July 22 99	12	3.5	11.5 ± 5.5	10	9	26
Xcalak North	XCN	Fringing	18 13 43	87 49 51	July 13 99	12	3.5	9.0 ± 4.5	10	11	27
Xcalak Center	XCC	Fringing	18 13 09	87 49 54	July 14 99	12	3.5	9.5 ± 3.0	10	8	22
Xcalak South	XCS	Fringing	18 12 39	87 49 47	July 15 99	12	3	7.5 ± 4.5	10	10	25

[1]From Ruiz et al. (this volume)
[2]Excluding any *Epinephelus cruentatus* and *E. fulvus*.

Table 2. Sighting frequency and mean density of the 25 most frequently sighted juvenile fish species in the "all species" belt transect surveys in central-southern Quintana Roo, México. * = AGRRA species.

Species name	Sighting frequency (%)[1]	Density (#/100m^2)
Halichores garnoti	83	13.20
Stegastes partitus	76	13.37
**Sparisoma aurofrenatum*	64	5.28
Thalasoma bifasciatum	57	13.54
Chromis cyanea	52	26.07
**Acanthurus coerules*	51	3.04
**Acanthurus bahianus*	48	3.31
**Sparisoma viride*	35	1.69
**Cephalopholis fulva (=Epinephelus fulvus)*[2]	32	1.44
**Holacanthus tricolor*	32	1.33
Cantigaster rostrata	29	1.30
Stegastes dorsopunicans	28	1.50
**Scarus iserti (=S. croicensis)*[2]	28	3.09
Stegastes planifrons	28	1.93
**Bodianus rufus*	22	1.00
**Cephalopholis cruentata (=Epinephelus cruentatus)*[2]	22	0.96
Clepticus parrae	19	17.50
Halichoeres maculipinna	14	0.57
**Chaetodon capistratus*	12	0.63
Stegastes variabilis	11	0.43
Pseudopeneus maculatus	11	0.39
Gramma loreto	11	0.72
**Sparisoma radians*	10	0.76
**Sparisoma atomarium*	10	0.48
**Lutjanus apodos*	9	1.00

[1]Sighting frequency (%) = percentage of transects in which the species was recorded.
[2]Genus and/or species names according to Eschmeyer's (1998) revision.

Table 3. Density (mean ± standard deviation) of juvenile AGRRA fishes by site in central-southern Quintana Roo, México.

Site name	Herbivores (#/100m²)		Carnivores (#/100m²)			Macroalgal Index[2]
	Acanthuridae	Scaridae	Haemulidae	Lutjanidae	Serranidae[1]	
Central						
Boca Paila N	2.7 ± 3.2	4.1 ± 5.0		0.2 ± 4.0		90
Boca Paila C	3.6 ± 3.0	3.5 ± 3.0				130
Boca Paila S	1.8 ± 1.0	2.6 ± 3.0				113
Punta Yuyum N	2.7 ± 2.0	4.6 ± 4.0		0.003		96
Punta Yuyum C	1.6 ± 4.0	5.8 ± 3.0		7.3 ± 0.7		81
Punta Yuyum S	2.5 ± 0.7	2.5 ± 3.0				81
Punta Allen N	2.5± 0.7	2.9 ± 2.0				142
Punta Allen C	4.0 ± 2.0	3.5 ± 1.0			0.003	116
Punta Allen S	3.0 ± 0.9	2.7 ± 2.0				126
Southern						
Mahahual N	0.3	1.4 ± 0.7		0.007		64
Mahahual C	0.3	4.6 ± 3.0				108
Mahahual S	1.3	5.9 ± 8.0				74
Xahuayxol N	3.6 ± 0.9	1.5 ± 1.0	0.003	0.003		75
Xahuayxol C	3.7 ± 3.0	1.4 ± 1.0	0.003	0.003		83
Xahuayxol S	1.6 ± 8.0	1.0 ± 0.4		0.007		71
Xcalak N	4.7 ± 3.0	1.9 ± 2.0		0.007		52
Xcalak C	4.6 ± 0.9	3.0 ± 3.0				49
Xcalak S	4.2 ± 2.0	2.6 ± 3.0	0.013	0.017		53

[1] *Epinephelus* spp. (excluding any *E. cruentatus* and *E. fulvus)* and *Mycteroperca* spp.
[2]From Ruiz et al. (this volume)