A Comparison of Fish Communities Between Protected and Unprotected Areas of the Belize Reef Ecosystem: Implications for Conservation and Management

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ABSTRACT

A visual census of fishes inhabiting three habitats (backreef, reef crest/cut, and forereef) on the barrier reef and two offshore atolls of Belize indicated differences in relative abundance of dominant and economically valuable fishes among habitats and between marine reserve and unprotected areas. The forereef had the greatest number of species, but diversity (H') was highest in the cuts. Fish abundance was also greatest on the forereef. In atoll forereef and barrier reef cut habitats, individuals and species per observation were greater in protected areas. Larger groupers (Nassau, black) and graysby were more abundant in protected habitats, while small coney were more abundant in unprotected sites. The dominant snappers (yellowtail, schoolmaster, gray, mahogany) were more abundant in reserve areas. Abundance of grunts varied, depending on habitat and site (atoll vs barrier reef). Herbivorous acanthurids and scarids were more abundant at unprotected sites. The visual census method is useful for evaluating the effects of marine sanctuary designation on the fish community; however, extensive pre-and postdesignation surveys are needed.

KEY WORDS: Caribbean sea, community structure, reef, reserve, Lutjanidae, Serranidae.

INTRODUCTION

The coral reef ecosystem of Belize consists of 260 km of barrier and fringing reef extending from Mexico to Bahia Honduras, and it includes three offshore coral atolls (Figure 1). The Belizean reef complex comprises reef, seagrass, and mangrove habitats critical to the life history of many species of economic importance in the Greater Caribbean Region. However, growth in tourism, fishing, and human population have increased demands on these relatively pristine coastal and marine systems (Robert Nicolait & Associates, 1984). Pollution resulting from residential and commercial coastal developments, accidental discharges from vessels, marine debris, littering, siltation of the reef from dredging operations and chemical runoff from

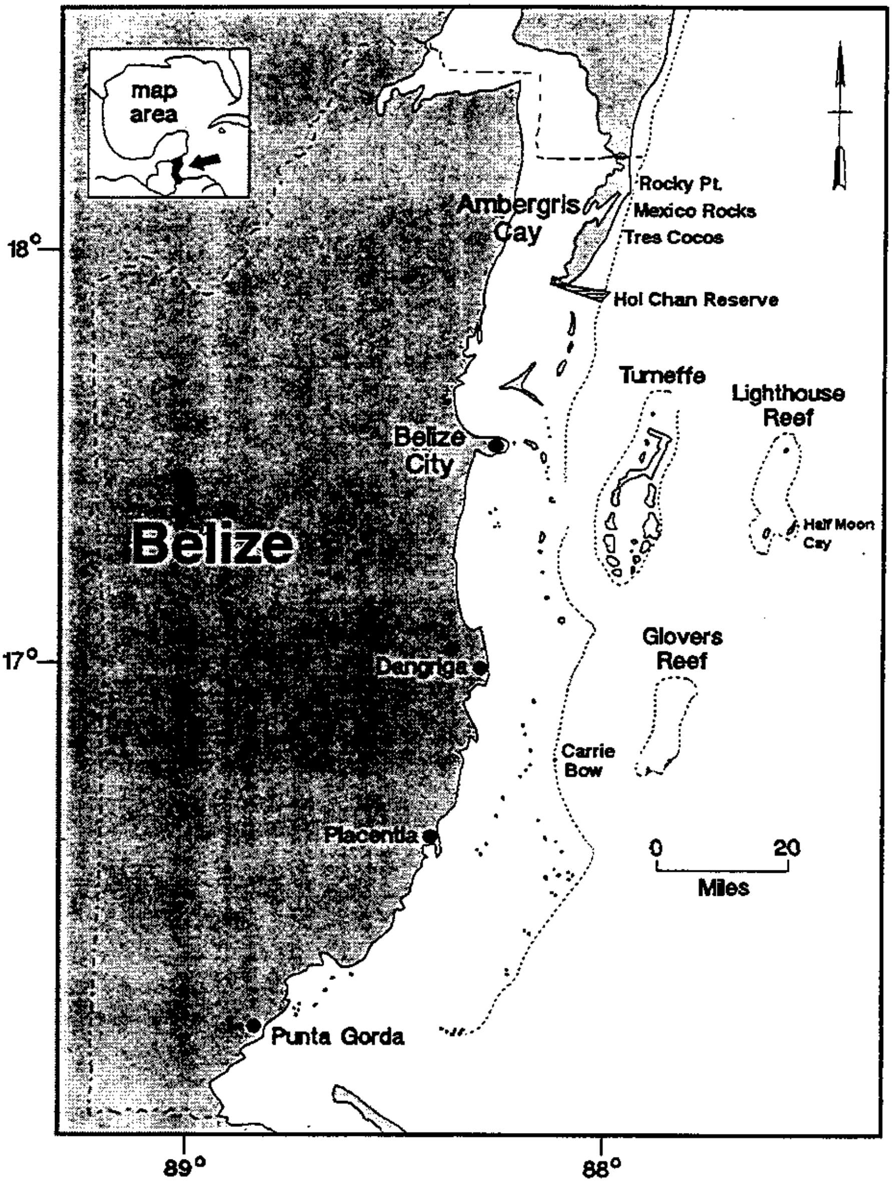

Figure 1. Map of Belize, showing sampling areas referred to in Table 1 and the text, and location of spawning aggregations of Nassau grouper.

increased agricultural production is an increasing problem. Overfishing has depleted once abundant stocks of conch, lobster (Gibson, 1991), and finfish such as groupers and snappers (Robert Nicolait & Associates, 1984; Price *et al.*, 1990).

As in many other tropical and subtropical regions, where multispecies fisheries and complex habitats and life history patterns confound traditional management methods (*e. g.*, minimum sizes, gear or seasonal restrictions), an approach to the conservation of finfish stocks and biodiversity has been the establishment of protected areas (Randall, 1982; Buxton and Smale, 1989; Alcala and Russ, 1990; Plan Development Team, 1990; Rigney, 1991). In 1982, Belize established the Half Moon Caye Natural Monument on Lighthouse Reef Atoll, and in 1987, the Hol Chan Marine Reserve was established on the barrier reef and adjacent lagoon. The Hol Chan Marine Reserve has been well received by resource managers, tour operators and tourists, and serves as a catalyst for the creation of other parks in the region, including a marine reserve on Glovers Reef Atoll (Gibson, 1988; Carter *et al.*, in press[a]; Carter *et al.*, in press[b]).

Marine reserves have been increasingly utilized for a variety of reasons, with fishery management or enhancement as a secondary consideration (Plan Development Team, 1990). In spite of the increasing numbers of marine reserves and parks established for conservation and attraction of tourists, particularly in the Caribbean (Randall, 1982), little data exist that can be used to evaluate the efficacy of these reserves in restoring reef fish communities to their former levels of biomass, diversity and structure. Indeed, it is not known if marine reserves in the Caribbean are useful in restoring stocks of grouper, snapper, grunts and other heavily fished groups. Because many reef fishes establish territories, undertake spawning migrations to distant spawning banks, or have larval stages that may be dispersed over a wide area, it is unknown if a relatively small reserve area can be restored to previous conditions, or if recruits from resident fish in the reserve are lost, or if recruitment to the reserve is dependent upon spawning in "upstream" unprotected areas.

The use of tropical marine resources is an issue of growing importance in Belize, where specific fishery and tourism management goals have been addressed by the establishment of marine reserve areas. The purpose of this investigation was to compare species composition and abundance of fishes in reserve areas to similar habitats in unprotected sites. A secondary purpose was to determine if the visual census technique could be useful for evaluating the effects of marine reserve designation on the fish community and exploited populations of finfish on Belizean reefs. This paper reports the results of a visual census survey used to compare the relative abundance and community structure of fishes in forereef, reef cut and backreef habitats between protected and unprotected areas of the Belizean coral reef complex.

METHODS

A visual census survey of reef fish communities was conducted in the vicinity of Ambergris Cay on the Barrier reef, and on two offshore atolls (Figure 1). Sites near Ambergris Cay included two cuts through the reef crest ("cut" habitat) that were similar in all respects, with the exception that one was in the Hol Chan Marine Reserve, and the other (Tres Cocos) was in a heavily fished area near the fishing community of San Pedro Town. Two additional unprotected sites near Ambergris Cay, Mexico Rocks and Rocky Point, were also censused. Habitats sampled near Ambergris Cay included the forereef, reef crest/cut and backreef. The majority of effort concentrated on reef cut sites at Hol Chan and Tres Cocos (Table 1), since barrier reef cuts are traditionally heavily fished areas. These two sites consisted of a 50 m wide cut thorough the barrier reef. The cuts are 5-9 m deep, and consist of boulder corals (*Montastrea annularis* and *M. cavernosa*), brain corals (*Diploria* spp.) and coral rock. Shallower portions of the crest lining the cuts consist of elkhorn (*Acropora palmata*) and staghorn (*A. cervicornis*) corals. The channel in the cuts consists of coral sand, with occasional boulder and brain coral heads. Reef cut samples included those in Hol Chan Marine Reserve (n=41), and a similar cut, Tres Cocos (n=35), located 9 km north of Hol Chan.

Backreef sites were sampled at Hol Chan (n=31) and Tres Cocos (n=60, and also at Mexico Rocks (n=13) off Ambergris Cay and at Carrie Bow Cay (n=28), 120 km south of Hol Chan. Backreef sites included lagoon patch reefs interspersed in seagrass, and the adjacent mangrove-lined lagoon. Fish assemblages in those areas were compared to barrier reef cuts; however, sites for comparison of abundance of selected species for reserve effects on the barrier reef were limited to cuts through the barrier reef crest.

Atoll sites included several reef habitats in and near the Half Moon Caye Natural Monument on Lighthouse Reef atoll and in similar unprotected habitats at Glovers Reef (Figure 1). These atolls possess the best developed reef growth and the greatest variety of reef types in the Caribbean (Dahl *et al.*, 1974). Most sampling concentrated on the forereef (Table 1). The forereef at Lighthouse and Glovers consists of high buttress spur and groove, with sand channels cutting through the outer reef ridge, before dropping off at sheer walls into deep water. Visual census points were conducted among the spurs and outer ridge, to a depth of 21 m. Forty-five points were censused in Half Moon Caye Natural Monument on Lighthouse Reef Atoll, and 75 samples were taken in similar habitats on Glovers Reef Atoll.

The habitats associated with the Belize barrier reef, including the area near Ambergris Cay, have been described in detail (Craig, 1966; Rützler and Macintyre, 1982; Perkins and Carr, 1985; Carter *et al.*, 1988; Wells, 1988). Descriptions of the Glovers Reef Atoll can be found in Dahl *et al.* (1974) and Wallace and Schafersman (1977); habitats at Lighthouse are similar to those at

Table 1. Sampling sites, habitats and number of samples collected by visual census in Belize.

Sites	Number of Samples/Habitat Backreef	Reef Cut	Forereef
Barrier Reef			
Rocky Point		9	
Mexico Rocks	13		
Tres Cocos	6	34	
Hol Chan Marine Reserve	31	41	13
Carrie Bow Cay	28	6	40
Atoll			
Lighthouse Reef (Half Moon Caye)	1		45
Glovers Reef	1	15	75
Total	80	105	173

Glovers (Hay, 1984; Wells, 1988). Portions of Lighthouse Reef atoll are protected because they lie within the Half Moon Caye Natural Monument, maintained by the Belize Audubon Society. Fishing is prohibited within a 6.4 km radius around Half Moon Caye (Wells, 1988) and the site is frequented by live-aboard dive boats and birders, which discourages any fishing activity at sites sampled on that atoll. Hol Chan Marine Reserve on the barrier reef is patrolled by park rangers, and fishing is prohibited.

Sampling consisted of randomly chosen visual census points, which were censused using scuba and the method of Bohnsack and Bannerot (1986). This method has proven to be suitable for describing reef fish community structure, and for making comparisons of fish abundance and community structure among sites and habitats (Bohnsack and Talbot, 1980; Bohnsack, 1982; Bohnsack and Bannerot, 1986; Clavijo *et al.*, 1989). This method consists of a diver listing the fish species seen in an imaginary cylinder in a five-minute period at randomly selected points within a habitat at a given site. Counts or estimates of abundance and minimum, maximum and mean length were then recorded. Data were recorded on underwater slates and transcribed during surface intervals.

Assemblages of fishes were described from barrier reef cuts and backreefs and atoll forereefs. For comparisons of abundance of economically valuable predatory species (*e.g.*, groupers, snappers, grunts), and species of interest from the other trophic levels (*e.g.*, surgeonfishes, parrotfishes), reef crest cuts at Tres Cocos and Hol Chan, and forereefs at Glovers and Lighthouse, were compared. Mean abundance and mean total length were compared using analysis of variance followed by the Scheffe multiple range test to determine which means were significantly different. Log transformation of the abundance data (numbers per point count) were used since log transformation reduced heteroscedacticity and made variances more homogeneous (Elliot, 1977; Bortone, 1983). Trophic level of species examined was determined from published feeding studies (Randall, 1967) and reviews (Kaufman and Ebersole, 1984).

Similarity indices were calculated to determine similarity among habitats sampled, and between sites within habitats. Cluster analysis was used to compare similarity in species composition and relative abundance between protected and unprotected sites, within a habitat type. Because sample sizes among habitats and sites were not equal, the data were percent-standardized (Boesch, 1977; Bortone, 1983). The Bray-Curtis coefficient (Bray and Curtis, 1957) was to measure similarity among site/habitat entities and species distributions, and flexible sorting (Lance and Williams, 1967) was used to group clustered entities (Clifford and Stephenson, 1975; Boesch, 1977).

Additional measures of community structure, species diversity (H') and number of species per census point, were calculated for collections by habitat and site. Diversity (H') was calculated according to the method of Pielou (1969).

RESULTS

Over 150 species from 47 families were observed and counted at 356 visual census points (Appendix I). Species accumulation curves indicated that the number of points censused was adequate to sample the diurnally active species amenable to visual census.

Fish abundance and species composition differed among the three habitats sampled. Overall fish abundance was greatest on the forereef (Table 2); however relative abundance on the forereef was not significantly greater than the backreef. The backreef had the greatest variation in mean number of fish per observation. The reef cut habitat was lowest in overall fish abundance, although diversity was high (Table 2, Figure 2).

Species composition differed among the three habitat zones sampled (Table 3). The backreef was dominated by dwarf herring (*Jenkinsia lamprotaenia*) and juvenile grunts, (*Haemulon* spp.) and wrasses (*Halichoeres bivittatus, Thalassoma bifasciatum, Clepticus parrai*). Wrasses dominated in reef cut and forereef habitats, but *T. bifasciatum* and *H. bivattatus* were most abundant on the reef cut, whereas *C. parrai* was the dominant wrasse on the forereef. Damselfishes (*C. cyaneus*) and wrasses (*C. parrai, T. bifasciatum*) on the forereef consisted mainly of water-column plankton pickers, whereas benthivorous and herbivorous wrasses and damselfishes (*H. bivittatus, P. partitus*) dominated in the reef cut and backreef habitats. Differences among zones in diversity and fish density resulted from shifts in relative abundance and composition of dominant species (Table 4). The backreef had significantly

Table 2. Mean, standard deviation and range of number of individuals per observation for backreef, reef cut and forereef visual census point counts. Means that were significantly different (0.05 level) are indicated by *.

Habitat	Mean Number of Individuals Per Observation	Standard Deviation	Range
Backreef (n=80)	149.98	225.80	1-1134
Reef cut (n=105)	88.30*	105.88	7-824
Forereef (n=173)	153.09	154.67	27-1239

Table 4. Mean number per observation of dominant fishes from reef and lagoon habitats in Belize. Dominant fishes include those that ranked among the top five within one of the three habitats. Within-species comparisons that are significantly different (0.05 level) are indicated by *.

Species	Backreef	Reef Cut	Forereef
Jenkinsia lamprotaenia	50.12*	0	0
Gramma melacara	0	0	7.54*
Haemulon plumeri	7.86	0.22	0.24
Haemulon sciurus	8.58	3.56	0.30*
Abudefduf saxatilis	1.02	3.98	1.65
Chromis cyaneus	0.91	0.08	32.24*
Pomacentrus fuscus	5.46*	1.74	1.11
Pomacentrus partitus	5.26	4.28	12.65*
Clepticus parrai	3.46	0	31.50*
Halichoeres bivittatus	6.92	4.70	0.54*
Thalassoma bifasciatum	5.02*	11.30	12.73
Acanthurus coeruleus	2.50	3.94	3.08

Table 6. Percent similarity in species composition of Belize reef habitats, based on the Bray-Curtis quantitative similarity coefficient.

	Reef Cut	Forereef
Backreef	0.467	0.204
Reef Cut		0.295

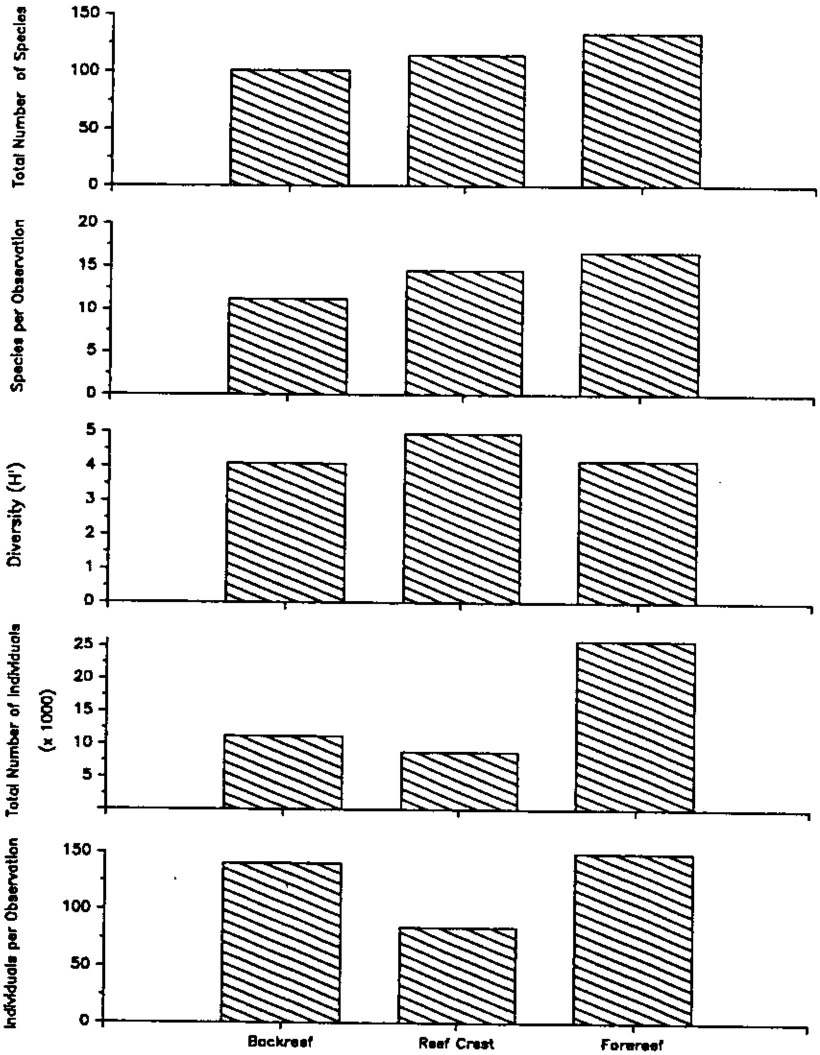

Figure 2. Abundance and diversity values for reef fish on reef habitats sampled by visual census.

Table 3. Abundance (mean number per observation) of the ten most abundant species from backreef, reef cut and forereef habitats. Species within habitats listed by rank abundance.

BACKREEF		REEFCUT		FOREREEF	
Jenkinsia lamprotaenia	51.1	*Thalassoma bifasciatum*	11.3	*Chromis cyaneus*	32.2
Haemulon sciurus	8.6	*Halichoeres bivattatus*	4.7	*Clepticus parrai*	31.5
Haemulon plumeri	7.9	*Pomacentrus partitus*	4.3	*Thalassoma bifasciatum*	12.7
Halichoeres bivittatus	6.9	*Abudefduf saxatilis*	4.0	*Pomacentrus partitus*	12.6
Pomacentrus fuscus	5.5	*Acanthurus coeruleus*	3.9	*Gramma melacara*	7.5
Pomacentrus partitus	5.3	*Haemulon sciurus*	3.6	*Ocyurus chrysurus*	5.3
Thalassoma bifasciatum	5.0	*Scarus croicensis*	3.1	*Chromis multilineatus*	5.0
Scarus croicensis	4.9	*Acanthurus bahianus*	3.0	*Gramma loreto*	4.6
Acanthurus bahianus	3.8	*Halichoeres garnoti*	2.9	*Scarus croicensis*	4.3
Clepticus parrai	3.5	*Haemulon flavolineatum*	2.2	*Pomacentrus planifrons*	3.3

higher (relative to other zones) densities of *J. lampeotaenia* and *P. fuscus*. *Thalassoma bifasciatum* was significantly lower in abundance in the backreef zone. The reef cut had low species abundances (Table 4) and species that were usually found in other habitats as well. No dominant species was significantly greater in abundance in reef cut habitats than in other habitats (Table 4).

Many dominant species on the forereef were significantly greater in abundance there than in the other two habitats (Table 4). *Haemulon sciurus* and *H. bivittatus* were found in significantly lower numbers on the forereef than in other habitats. The forereef had many unique species (Table 5), and more dominant species had significantly greater abundance on the forereef (Table 4). Of the ten most abundant species within any one habitat, only one, *Gramma melacara*, was unique to a particular zone, and was found only on the forereef. An additional 15 species were unique to the forereef, compared to four species each for the backreef and reef cut.

Bray-Curtis similarity indices indicated that the reef cut and backreef were most similar in species composition, sharing six dominant species (Table 6, Table 3). The backreef was least similar to the forereef, and only four dominant species were shared between those two habitats.

In addition to having many unique species, the forereef had the greatest species richness, as measured by total number of species (133) and mean number of species per observation (16.6); however, H' diversity was lower in the forereef than in the reef cut habitat, because of dominance of the community by large numbers of individuals of a few species (Figure 2). The reef cut had the higher H' diversity, in spite of having significantly (0.05 level) lower number of species per observation than the forereef (Figure 2). The backreef had the lowest diversity of the three habitats.

A comparison of relative abundance and diversity of protected and unprotected sites indicated that protected forereef habitats at Lighthouse Reef had significantly more fish per observation than those compared at unprotected Glovers Reef (Table 7). The protected reef cut at Hol Chan also had significantly more fish per observation than the reef cut at Tres Cocos (Table 7). Number of species per point was greater (but not significantly so) in protected areas for the reef cut and forereef (Table 8). Among protected and unprotected habitats along the barrier reef and on the atolls, species richness was greatest in Hol Chan Marine Reserve reef cut, followed by Lighthouse forereef; species richness was very similar in the two nonprotected sites (Glovers and Tres Cocos), in spite of habitat differences. H' diversity was lower in the protected areas within both habitats (Figure 3), but especially at Lighthouse.

Community structure varied among habitats, but also varied within habitats but among the reef sites examined (reserve vs. non-reserve; atoll vs. barrier reef). Abundance of some species or groups of species was apparently determined by sanctuary designation. A comparison of the dominant species on

Table 5. Species unique to each habitat surveyed by visual census.

BACKREEF	REEF CUT	FOREREEF
Atherinomorus stipes	*Bothus lunatus*	*Abudefduf taurus*
Jenkinsia lamprotaenia	*Halichoeres caudalis*	*Aluterus scripta*
Serranus baldwini	*Ophioblennius atlanticus*	*Amblycirrhitus pinos*
Pomacentrus pictus	*Serranus annularis*	*Apogon townsendi*
		Canthidermis sufflamen
		Caranx bartholomaei
		Chromis insolatus
		Equetus lanceolatus
		Gramma melacara
		Holocentrus vexillarius
		Inermia vittata
		Kyphosus sectatrix
		Mycteroperca tigris
		Nystactichthys halis
		Scarus coelestinus
		Sparisoma atomarium

Table 7. Mean, standard deviation and range of number of individuals per observation for visual census point counts on the forereef of Belize atolls, and in the crest cuts of the barrier reef. Means were significantly different (0.05 level).

ATOLL FOREREEF			
Reef	**Mean Number of Individuals Per Observation**	**Standard Deviation**	**Range**
Glovers (n=75)	118.72	130.91	27-779
Lighthouse (protected) (n=45)	245.33	228.43	47-1239
BARRIER REEF CUT			
Reef	**Mean Number of Individuals Per Observation**	**Standard Deviation**	**Range**
Tres Cocos (n=35)	62.89	70.09	18-372
Hol Chan (protected) (n=41)	132.10	141.10	9-824

the forereef at Glovers and Lighthouse indicated a greater abundance of creole wrasse, *Clepticus parrai*, at Lighthouse (Table 9). Abundance of blue chromis, *Chromis cyaneus*, was twice as great at Lighthouse than at Glovers, and the rank abundance of these two species differed between the two sites. Bluehead wrasse, *Thalassoma bifasciatum*, were nearly equal in abundance on the two atolls, but ranking of this species was quite different between the two sites. Blackcap basslet, *Gramma melacara*, were much more abundant at Lighthouse than at Glovers.

Bray-Curtis similarity values calculated to compare habitats between protected and unprotected areas indicated high similarity in the forereef fish fauna at Glovers and Lighthouse, with the collections at the reef crest on Glovers being quite distinct from the forereef habitats (Table 10). The increased abundance of dominant species at Lighthouse Reef, together with differences between Lighthouse and Glovers in rank abundance, resulted in 71.1% similarity in the fish fauna of the forereef between these two sites. The forereef sites at Lighthouse and Glovers, however, were higher in percent similarity than were other comparisons (Table 10).

There were marked differences in the fish fauna between the two reef cut habitats sampled on the barrier reef, and between those sites and a backreef site

Table 8. Mean number of species per observation for atoll forereef and barrier reef cut habitats in Belize. Means were not significantly different at the 0.05 level (ANOVA).

	ATOLL FOREREEF		
Reef	**Mean Number of Individuals Per Observation**	**Standard Deviation**	**Range**
Glovers (n=75)	14.78	4.80	4-36
Lighthouse (n=45)	15.69	3.93	6-25

	BARRIER REEF CUT		
Reef	**Mean Number of Individuals Per Observation**	**Standard Deviation**	**Range**
Tres Cocos (n=35)	14.71	3.93	6-23
Hol Chan (n=41)	16.14	5.65	5-28

Table 10. Similarity in species composition of Belize atoll and barrier reef habitats, based on the Bray-Curtis quantitative similarity coefficient.

	ATOLL SITES	
	Glovers Reef Cut	**Glovers Forereef**
Lighthouse Forereef	0.087	0.711
Glovers Reef Cut		0.119

	BARRIER REEF SITES		
	Hol Chan Backreef	**Hol Chan Reef Cut**	**Tres Cocos Backreef**
Hol Chan Reef Cut	0.411		
Tres Cocos Backreef	0.092	0.088	
Tres Cocos Reef Cut	0.165	0.329	0.121

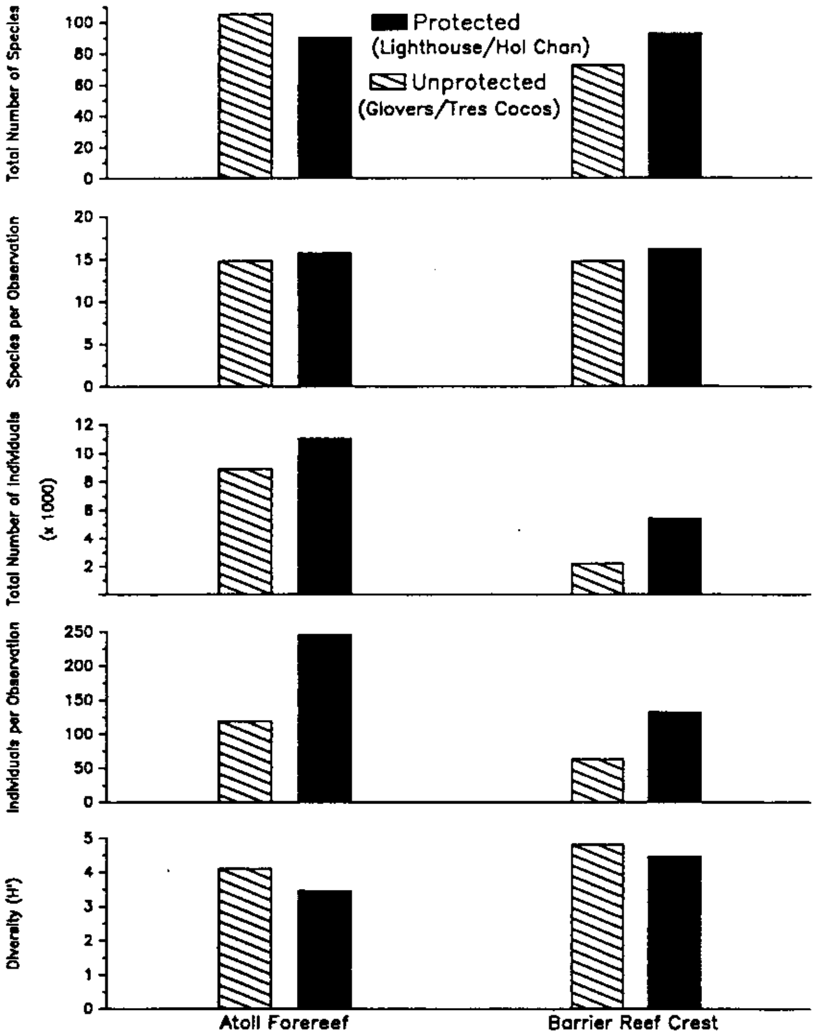

Figure 3. Comparison of abundance and diversity values for reef fish sampled by visual census in protected reserve and unprotected reef habitats.

Table 9. Abundance (mean number per observation) of the ten most abundant species from the forereef on the two atolls, and from the reef crest cuts at two sites on the barrier reef near Ambergris Cay, Belize. Species within areas listed by rank abundance.

ATOLL FOREREEF SITES			
GLOVERS		**LIGHTHOUSE**	
Chromis cyaneus	30.1	*Clepticus parrai*	65.0
Clepticus parrai	24.4	*Chromis cyaneus*	61.0
Thalassoma bifasciatum	9.6	*Gramma melacara*	23.7
Gramma loreto	5.5	*Pomacentrus partitus*	19.5
Pomacentrus partitus	4.6	*Chromis multilineatus*	14.9
Coryphopterus personatus	4.1	*Ocyurus chrysurus*	12.4
Ocyurus chrysurus	4.1	*Thalassoma bifasciatum*	8.7
Acanthurus coeruleus	4.1	*Gramma loreto*	8.2
Gramma melacara	3.2	*Coryphopterus personatus*	3.6
Chromis multilineatus	2.8	*Chromis insolatus*	2.8
BARRIER REEF CUT			
HOL CHAN		**TRES COCOS**	
Abudefduf saxatilis	9.2	*Thalassoma bifasciatum*	11.3
Haemulon sciurus	7.4	*Halichoeres bivittata*	6.1
Pomacentrus partitus	7.0	*Haemulon flavolineatum*	5.0
Thalassoma bifasciatum	6.6	*Halichoeres garnoti*	4.6
Halichoeres bivittatus	4.7	*Chromis multilineatus*	4.2
Lutjanus griseus	4.4	*Acanthurus coeruleus*	2.8
Scarus croicensis	4.1	*Acanthurus bahianus*	2.8
Lutjanus mahogoni	3.8	*Scarus croicensis*	1.9
Ocyurus chrysurus	3.1	*Haemulon sciurus*	1.6
Halichoeres cyanocephalus	2.7	*Sparisoma viride*	1.5

sampled at Tres Cocos (Table 9, Table 10). Damselfishes (*A. saxatilis, P. partitus*) and a grunt (*H. sciurus*) were the dominant species at Hol Chan, whereas wrasses (*T. bifasciatum, H. bivittatus*) and a smaller species of grunt (*H. flavolineatum*) dominated Tres Cocos. Herbivorous fishes such as *Acanthurus* spp. and *Sparisoma viride* ranked among the dominant species at Tres Cocos, but were not as abundant at Hol Chan. The snappers, *Lutjanus griseus, L. mahogoni*, and *Ocyurus chrysurus*, ranked among the most abundant species at Hol Chan (Table 9), but were rare at Tres Cocos (see below). Larger carnivorous species such as snappers and groupers were rare or absent at Tres Cocos, herbivorous species were more abundant at that site.

Protected reef cut habitats were more dissimilar to unprotected cut sites than was noted in forereef comparisons between protected and unprotected areas

(Table 10). Whereas Glovers and Lighthouse forereef sites showed 71.1% similarity, Hol Chan and Tres Cocos cuts had only 32.9% similarity. On the atoll forereefs, two dominant species were much higher in abundance than other species (Table 9), and this accounted for high similarity between Glovers and Lighthouse forereef collections. Greatest among-site similarity in the Ambergris Cay collections was noted between cut collections within the Hol Chan Marine Reserve (Table 10). Tres Cocos, on the other hand, showed low similarity between cut and backreef habitats (12.1%).

Three groups of predatory fishery species, and two groups of herbivorous species were enumerated for comparison between reserve and non-reserve areas. Among the groupers (family Serranidae), large species such *E. striatus* and *M. bonaci* were more abundant in forereef (*E. striatus*) and cut (*M. bonaci*) habitats (Table 11), with mean abundance usually significant higher in protected areas (Table 12). The intermediate sized graysby (*E. cruentatus*) was also most abundant in protected areas. The small coney (*E. fulvus*) was most abundant in non-protected habitats, especially on the forereef.

Yellowtail snapper, *O. Chysurus*, was the most abundant snapper, and was significantly more abundant on the forereef (Table 11). On the atoll forereef, Lighthouse had significantly more yellowtail snapper than did Glovers; on the barrier reef cut, yellowtail snapper were significantly more abundant at Hol Chan cut (Table 13). Schoolmaster, *L. apodus*, preferred backreef habitats (Table 11), but were more abundant in protected forereef and cut habitats than in unprotected areas. Gray snapper (*L. griseus*) and dog snapper (*L. jocu*) were significantly more abundant at Hol Chan than at Tres Cocos reef cut. Mean length of dominant snappers was also generally greater in protected areas (Table 13).

Several species of grunts were abundant in the habitats sampled (Table 14). Grunts were often more abundant in unprotected sites. The most abundant grunt, *H. sciurus* (bluestriped grunt), was common in the cut habitat (Table 11), and was more abundant at Hol Chan than at Tres Cocos on the barrier reef. In forereef habitats (where they were not abundant), mean number per observation was significantly greater at the unprotected site. On the other hand, white grunt (*H. plumieri*) were significantly more abundant at Tres Cocos than at Hol Chan, but were more abundant in protected forereef habitats on the atolls. French grunts (*H. flavolineatum*), were most abundant in backreef habitats (Table 11) and were always more abundant in unprotected sites (significantly so at Tres Cocos vs. Hol Chan).

Relative abundance of three acanthurids was examined to determine the effects of reserve designation on other trophic levels (herbivore). For the two most abundant acanthurids, abundance in barrier reef cuts was significantly greater in unprotected sites (Table 15). Blue tang was the most abundant surgeonfish, and it was most abundant in the cuts (Table 11). It was more

Table 11. Rank of habitats by mean abundance per observation for selected species of grouper, snapper, grunt, parrotfish and surgeonfish. Mean number per observation are given below each habitat. Means (log-transformed) that are underscored were not significantly different (ANOVA; Scheffe, α=0.05).

Epinephelus cruentatus	Forereef>Backreef>Cut 0.26 > 0.12 > 0.02
Epinephelus fulvus	Forereef>Cut>Backreef 0.70 > 0.34 > 0.06
Epinephelus guttatus	Forereef>Cut>Backreef 0.17 > 0.02 > 0
Epinephelus striatus	Forereef>Cut>Backreef 0.25 > 0.13 > 0
Mycteroperca bonaci	Cut>Forereef>Backreef 0.21 > 0.10 > 0.01
Lutjanus apodus	Backreef>Cut>Forereef 2.95 > 1.12 > 0.28
Lutjanus griseus	Cut>Backreef>Forereef 1.74 > 0.59 > 0.02
Lutjanus jocu	Cut>Backreef>Forereef 0.81 > 0.51 > 0.06
Lutjanus mahogani	Cut>Forereef>Backreef 1.58 > 0.12 > 0.02
Ocyurus chrysurus	Forereef>Cut>Backreef 5.39 > 1.53 > 1.10
Haemulon album	Cut>Backreef>Forereef 1.07 > 0.01 > 0.01
Haemulon aurolineatum	Backreef>Cut>Forereef 2.09 > 0.15 > 0
Haemulon flavolineatum	Backreef>Cut>Forereef 3.22 > 2.22 > 0.88
Haemulon plumeri	Backreef>Forereef>Cut 7.86 > 0.24 > 0.22
Haemulon sciurus	Backreef>Cut>Forereef 8.58 > 3.56 > 0.30
Acanthurus bahianus	Cut>Backreef>Forereef 3.80 > 3.09 > 1.89
Acanthurus chirurgus	Backreef>Cut>Forereef 0.69 > 0.54 > 0.10
Acanthurus coeruleus	Cut>Forereef>Backreef 3.94 > 3.08 > 2.50
Scarus croicensis	Forereef>Backreef>Cut 4.39 > 4.81 > 3.12
Scarus taeniopterus	Cut>Forereef>Backreef 1.10 > 0.79 > 0.10
Sparisoma aurofrenatum	Foereef>Cut>Backreef 1.62 > 0.80 > 0.84
Sparisoma chrysopterum	Cut>Backreef>Forereef 0.68 > 0.94 > 0.24
Sparisoma viride	Forereef>Cut>Backreef 0.99 > 0.78 > 0.50

Table 12. Comparison of mean abundance, log-transformed (log (x + 1), and mean length of dominant grouper species, between protected and unprotected sites in barrier reef cut and atoll forereef habitats. Barrier reef comparisons are between Hol Chan (HC; N=41) and Tres Cocos (TC; N=35) reef cuts. Atoll comparisons are between Glovers Reef (GR; N=75) and Lighthouse Reef (LH; N=45) forereefs. Means that are significantly different (*i.e.*, probability (P) that differences are due to random sampling variability alone is less than 0.05) are indicated by *. n=number of individuals in entire survey.

Species	Barrier Reef Cut	Atoll Forereef
Epinephelus fulvus (n=162)		
log (x + 1)	P<0.2759; TC>HC	P<0.1788; GR>LH
mean length	P<0.7871; TC>HC	P<0.2840; GR>LH
Epinephelus striatus (n=58)		
log (x + 1)	P<0.0042*; **HC>TC**	P<0.5656; LH>GR
mean length	no fish at TC	P<0.8534; GR>LH
Epinephelus cruentatus (n=57)		
log (x + 1)	P<0.3590; HC>TC	P<0.0159*; **LH>GR**
mean length	no fish at TC	P<0.9543; GR>LH
Mycteroperca bonaci (n=41)		
log (x + 1)	P<0.0023*; **HC>TC**	P<0.0011*; **LH>GR**
mean length	no fish at TC	P<0.0973; LH>GR
Epinephelus guttatus (n=32)		
log (x + 1)	P<0.3590; HC>TC	P<0.3384; LH>GR
mean length	no fish at TC	P<0.2482; LH>GR

abundant at Lighthouse than at Glovers on the forereef, but in cut habitats, it was significantly more abundant at Tres Cocos than in the Hol Chan reserve. For ocean surgeon (*A. bahianus*), abundance was greater in unprotected areas (Table 15), especially in the reef cut, the habitat of greatest abundance for this species (Table 11). For the third acanthurid, *A. chirurgus*, there was no significant difference in abundance between protected and unprotected sites in either habitat.

Scarus croicensis, the striped parrotfish, was the most abundant scarid, and was common in all habitats, especially the forereef and backreef (Table 11). On the barrier reef, striped parrotfish was significantly more abundant in the reserve, but this was not true offshore on the atolls (Table 16). In most cases, parrotfish were abundant at the unprotected sites. Redband parrotfish (*S. aurofrenatum*) and stoplight parrotfish (*S. viride*) were significantly more abundant at Tres Cocos than at Hol Chan; stoplight parrotfish on the forereef (the habitat of greatest abundance) were more abundant at Glovers (not significant) than at Lighthouse. Princess parrotfish (*S. taeniopterus*) was significantly more abundant at Glovers than at Lighthouse.

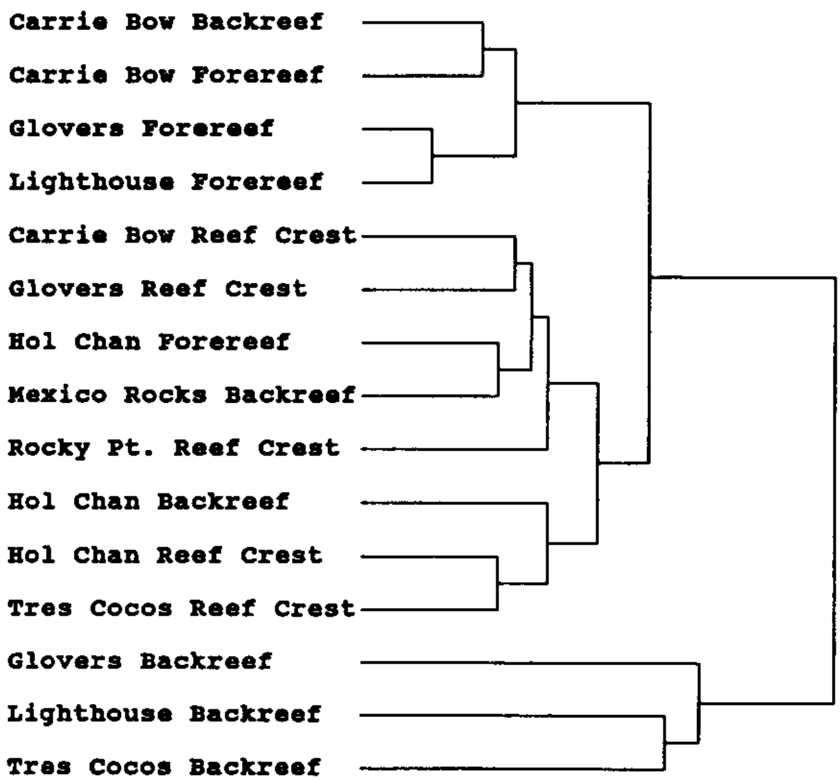

Figure 4. Dendrogram depicting similarity among visual census observations, pooled by habitat and collection site.

Table 13. Comparison of mean abundance, log-transformed (log (x + 1), and mean length of dominant snapper species, between protected and unprotected sites in barrier reef cut and atoll forereef habitats. Barrier reef comparisons are between Hol Chan (HC; N=41) and Tres Cocos (TC; N=35) reef cuts. Atoll comparisons are between Glovers Reef (GR; N=75) and Lighthouse Reef (LH; N=45) forereefs. Means that are significantly different (*i.e.*, probability (P) that differences are due to random sampling variability alone is less than 0.05) are indicated by *. n=number of individuals in entire survey.

Species	Barrier Reef Cut	Atoll Forereef
Ocyurus chrysurus (n=1182)		
log (x + 1)	P<0.0002*; **HC>TC**	P<0.0014*; **LH>GR**
mean length	P<0.0009*; **HC>TC**	P<0.2125; LH>GR
Lutjanus apodus (n=403)		
log (x + 1)	P<0.4812; HC>TC	P<0.1105; LH>GR
mean length	P<0.1053; HC>TC	P<0.5082; LH>GR
Lutjanus griseus (n=233)		
log (x + 1)	P<0.0224*; **HC>TC**	P<0.2854; GR>LH
mean length	no fish at TC	no fish at LH
Lutjanus mahogani (n=189)		
log (x + 1)	P<0.1190; HC>TC	P<0.5585; GR>LH
mean length	P<0.9655; HC>TC	P<0.4226; GR>LH
Lutjanus jocu (n=137)		
log (x + 1)	P<0.0002*; **HC>TC**	P<0.9731; LH>GR
mean length	P<0.0544; HC>TC	one obs. per site

Cluster analysis of visual census points pooled by habitat for all sites surveyed indicated that fish communities were structured by habitat and location (Figure 4). For example, high similarity was noted between forereef observations at Glovers and Lighthouse forereef, and at Hol Chan and Tres Cocos reef cut habitats. Similarly, backreef habitats at Glovers, Lighthouse and Tres Cocos clustered together.

DISCUSSION

Ranking of dominant species from the two habitats compared for reserve effects reveals differences in relative abundance of dominant species in reserve and unprotected sites, especially between Hol Chan and Tres Cocos. Small damselfishes, grunts and wrasses dominated at both sites, but wrasses dominated the fauna at Tres Cocos, whereas damselfish dominated at Hol Chan. Abundance rank of dominant species in barrier reef cut habitats indicated differences in trophic structure between the two sites. Dominant species at Hol Chan cut were a grazer on epifauna and epiflora (*A. saxatilis*), a predator on soft-bottom infauna and epifauna (*H. sciurus*), and a small planktivore (*P. partitus*). Tres Cocos cut was dominated by plankton pickers (*T. bifasciatum*)

Table 14. Comparison of mean abundance, log-transformed (log (x + 1), and mean length of dominant grunt species, between protected and unprotected sites in barrier reef cut and atoll forereef habitats. Barrier reef comparisons are between Hol Chan (HC; N=41) and Tres Cocos (TC; N=35) reef cuts. Atoll comparisons are between Glovers Reef (GR; N=75) and Lighthouse Reef (LH; N=45) forereefs. Means that are significantly different (*i.e.*, probability (P) that differences are due to random sampling variability alone is less than 0.05) are indicated by *. n=number of individuals in entire survey.

Species	**Barrier Reef Cut**	**Atoll Forereef**
Haemulon sciurus (n=1112)		
log (x + 1)	P<0.0943; HC>TC	P<0.0121*; **GR>LH**
mean length	P<0.6615; HC>TC	no fish at LH
Haemulon plumeri (n=694)		
log (x + 1)	P<0.0082*; **TC>HC**	P<0.0800; LH>GR
mean length	P<0.3494; HC>TC	P<0.4044; LH>GR
Haemulon flavolineatum (n=643)		
log (x + 1)	P<0.0116*; **TC>HC**	P<0.8258; GR>LH
mean length	P<0.8295; TC>HC	P<0.1092; LH>GR
Haemulon aurolineatum (n=183)		
log (x + 1)	P<0.1898; TC>HC	no fish at atoll
mean length	no fish at hC	sites
Haemulon album (n=115)		
log (x + 1)	P<0.1115; HC>TC	P<0.1980; LH>GR
mean length	no fish at TC	no fish at GR

and benthivores (*H. bivittatus, H. flavolineatum*) (Randall, 1967; Kaufman and Ebersole, 1984).

On the atolls, Lighthouse reef and Glovers reef had different species of plankton pickers (Randall, 1967) as the most abundant species. Whereas a highly mobile schooling planktivore was the most abundant species at Lighthouse, a site-associated schooling planktivore dominated at Glovers. The two most abundant species on the atoll forereef, *C. cyaneus* and *C. parrai* are both plankton picking species (Randall, 1967), and comprised about 50% of the fishes seen on the forereef. Because of the dominance of the atoll forereef by these two species, H' diversity was lower on the forereef than in the other two habitats.

Larger, commercially valuable species of grouper and snapper were more abundant in protected areas of Belize, as has been noted in previous studies of other reef reserves (Plan Development Team, 1990). Groupers and snappers are large, predatory fishes that feed mainly on other fishes, cephalopods, and larger benthic crustaceans (Randall, 1967; Parrish, 1987). Because of their role as top-level carnivores, it has been suggested that these piscivorous fishes are

Table 15. Comparison of mean abundance, log-transformed (log (x + 1), and mean length of surgeonfish species, between protected and unprotected sites in barrier reef cut and atoll forereef habitats. Barrier reef comparisons are between Hol Chan (HC; N=41) and Tres Cocos (TC; N=35) reef cuts. Atoll comparisons are between Glovers Reef (GR; N=75) and Lighthouse Reef (LH; N=45) forereefs. Means that are significantly different (*i.e.*, probability (P) that differences are due to random sampling variability alone is less than 0.05) are indicated by *. n=number of individuals in entire survey.

Species	**Barrier Reef Cut**	**Atoll Forereef**
Acanthurus coeruleus (n=1147)		
log (x + 1)	P<0.0050*; **TC>HC**	P<0.8234; LH>GR
mean length	P<0.9168; HC>TC	P<0.0258; LH>GR
Acanthurus bahianus (n=955)		
log (x + 1)	P<0.0006*; **TC>HC**	P<0.5896; GR>LH
mean length	P<0.0041*; **HC>TC**	P<0.2148; LH>GR
Acanthurus chirurgus (n=129)		
log (x + 1)	P<0.0649; HC>TC	P<0.3387; GR>LH
mean length	P<0.7821; HC>TC	P<0.2105; LH>GR

Table 16. Comparison of mean abundance, log-transformed (log (x + 1), and mean length of parrotfish species, between protected and unprotected sites in barrier reef cut and atoll forereef habitats. Barrier reef comparisons are between Hol Chan (HC; N=41) and Tres Cocos (TC; N=35) reef cuts. Atoll comparisons are between Glovers Reef (GR; N=75) and Lighthouse Reef (LH; N=45) forereefs. Means that are significantly different (*i.e.*, probability (P) that differences are due to random sampling variability alone is less than 0.05) are indicated by *. n=number of individuals in entire survey.

Species	**Barrier Reef Cut**	**Atoll Forereef**
Scarus croicensis (n=1472)		
log (x + 1)	P<0.0017*; **HC>TC**	P<0.1419; GR>LH
mean length	P<0.0001*; **TC>HC**	P<0.2320; LH>GR
Sparisoma aorofrenatum (n=431)		
log (x + 1)	P<0.0290*; **TC>HC**	P<0.3160; LH>GR
mean length	P<0.4275; TC>HC	P<0.4180; GR>LH
Sparisoma viride (n=294)		
log (x + 1)	P<0.0105*; **TC>HC**	P<0.4556; GR>LH
mean length	P<0.4862; TC>HC	P<0.9943; LH>GR
Scarus taeniopterus (n=261)		
log (x + 1)	P<0.6564; HC>TC	P<0.0447*; **GR>LH**
mean length	P<0.4608; TC>HC	P<0.5288; LH>GR
Sparisoma chrysopterum (n=187)		
log (x + 1)	P<0.4953; TC>HC	P<0.4608; GR>LH
mean length	P<0.4064; TC>HC	P<0.1044; LH>GR

important in structuring the community of fishes that make up the forage base for piscivores on the reef (Sale, 1980). Shpigel and Fishelson (1991) did not observe changes in prey species populations and diversity after experimental removal of groupers; however, their experiment was relatively short-lived, and within a small reef area, relative to the extent of habitat and the history of fishing pressure on the Belize barrier reef. In the protected areas studied herein, species richness (Measured as mean number of species per observation), was higher in the reserve areas than in unprotected sites. Apparently, the presence of large predators in the reserve allows more species to coexist through reducing competitive exclusion within prey fish populations, by predation on abundant prey species.

Unlike snappers and groupers, grunts did not appear to occur in increased numbers in reserve areas, and for some species (*H. sciurus, H. plumieri, H. flavolineatum*), abundance was sometimes significantly higher in the unprotected sites. Of the grunts examined, only French grunt (*H. flavolineatum*) were more abundant in unprotected sites in both habitats. Previous studies have also noted that French grunt were more abundant in unprotected sites than in reserves, while most other grunts were more abundant in protected sites (Plan Development Team, 1990). Randall (1967) noted that French grunt is a component of the largely fish diet of Nassau and black grouper in the Caribbean. Reduced abundance of these groupers in the unprotected areas of Belize probably results in increased abundance of French grunt, relative to reserve sites. In contrast to the small French grunt, large margate (*H. album*, reaching 50 cm in length) were more abundant in protected areas. The large size of this species may afford it protection from predation by snappers and groupers that are abundant in reserves. In addition, this haemulid may be more highly prized by fishermen because of its large size, and thus is more abundant in non-fished areas.

Although the white grunt (*H. plumieri*) were significantly more abundant at Tres Cocos than at Hol Chan, mean length was greater at Hol Chan (x=20 cm) than at Tres Cocos (x=17 cm). The reduced mean size of white grunt at Tres Cocos may be a result of heavy fishing pressure, as has been noted in other overexploited populations of reef fishes (Bohnsack, 1982; Plan Development Team, 1990; Collins and Sedberry, 1991). Mean length of other predatory fishes was often lower in unprotected sites in the present study

Larger white grunt occur on the forereef than in the cut, and this may explain their increased abundance in protected forereefs (they were lower in abundance in protected cut habitats). French grunts, the smallest species examined, was always more abundant in unprotected sites vs. protected areas. Perhaps French grunts replace larger white grunts that are apparently fished out of protected sites. French grunt may similarly replace larger bluestriped grunt (and margate) that are lower in abundance in unprotected reed cut habitats.

Like some of the grunts, and in contrast to the piscivorous snappers and groupers, algae-eating acanthurids (Randall, 1967) were usually more abundant in non-reserve areas. In the case of blue tang (*A. coeruleus*) and ocean surgeon (*A. bahianus*) in barrier reef cuts, abundance within Hol Chan Marine reserve was significantly less than in unprotected Tres Cocos. Like French grunt, *Acanthurus* spp. are important prey for groupers, including tiger grouper (*Mycteroperca tigris*), yellowfin grouper (*M. venenosa*) and Nassua grouper (Randall, 1967). Absence or rarity of these groupers from fished areas, especially on the barrier reef, probably results in increased abundance of acanthurids and other grouper prey species.

Many parrotfishes are also herbivorous (Randall, 1967), and most species examined were, like acanthurids, more abundant in non-reserve areas. The exception was the striped parrotfish (*S. croicensis*), which were higher in abundance in the reserve on the barrier reef, but this did not hold for the atolls. Redband parrotfish (*S. aurofrenatum*) and stoplight parrotfish (*S. viride*) were significantly more abundant in Tres Cocos reef cut than in Hol Chan cut, and princess parrotfish (*S. taeniopterus*) was significantly more abundant at Glovers than at Lighthouse. All of these parrotfishes are almost exclusively herbivorous on algae, and many are prey to large snappers and groupers (Randall, 1967). The abundance of these herbivorous prey species is impacted by reserve designation, apparently by protection of their predators.

It is apparent from the relative abundance of large predatory fishes, smaller omnivorous prey fishes, and herbivorous forage species, that fish communities are affected by fishing and reserve designation. Differences in fish community structure, including trophic structure, between similar habitats in protected and non-protected areas in Belize indicates that ecosystem overfishing (Russ, 1991) has occurred in some areas of the Belize reef system. Effects of fishing and sanctuary designation appear to be most evident near the fishing village of San Pedro, where fishing has historically been a major part of the economy and life of Ambergris Cay residents. Because effects of fishing on the Belize reef system are evident at the community level, *i.e.* changes in species composition, relative abundance, and trophic structure, complete protection is needed to restore the reef to previous structure of associated fish communities. The government and people of Belize have made tremendous progress in conservation of reef resources. An ultimate goal should be protection of 20-30% of the reef, to include all habitats, as has been recommended for restoration and conservation of reef fish stocks off the southeastern U.S. (Plan Development Team, 1990). Traditional management plans for individual species (*e.g.*, Carter and Marrow, 1991) should also be implemented.

The visual census documented differences in abundance of economically valuable reef fishes, and differences in community structure, between reserve and unprotected sites in Belize. Differences in community structure between reserve and unprotected habitats may indicate ecosystem overfishing. Future reserve designations should include extensive pre-and post-designation surveys, to further document that differences in community structure are a result of reserve designation.

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Appendix I. Phylogenetic list and rank abundance of fishes (N=45,915) observed at 358 stationary visual census points at reef sites in Belize.

FAMILY ***Species***	**Rank**
ORECTOLOBIDAE	
Ginglymostoma cirratum	147
DASTATIDAE	
Dasyatis americana	136
Urolophus jamaicensis	104
MYLIOBATIDAE	
Aetobatus narinari	115
ELOPIDAE	
Megalops atlanticus	164
MURAENIDAE	
Gymnothorax funebris	126
CONGRIDAE	
Nystactichthys halis	83
CLUPEIDAE	
Jenkinsia lamprotaenia	3
ENGRAULIDAE	
undetermined	52
SYNODONTIDAE	
Synodus sp.	126
Synodus intermedius	126
Synodus synodus	164
EXOCOETIDAE	
Hemiramphus brasiliensis	164
BELONIDAE	
Tylosurus crocodilus	99
ATHERINIDAE	
Atherinomorus stipes	79

Appendix I. (Continued).

FAMILY *Species*	**Rank**
HOLOCENTRIDAE	
Holocentrus sp.	113
Holocentrus ascensionis	104
Holocentrus rufus	36
Holocentrus vexillarius	136
AULOSTOMIDAE	
Aulostomus maculatus	97
SYNGNATHIDAE	
Syngnathus sp.	147
SERRANIDAE	
Epinephelus sp.	147
Epinephelus adscensionis	147
Epinephelus cruentatus	67
Epinephelus fulvus	38
Epinephelus guttatus	82
Epinephelus itajara	164
Epinephelus striatus	66
Hypoplectrus unicolor	58
Mycteroperca sp.	164
Mycteroperca bonaci	71
Mycteroperca tigris	104
Serranus sp.	126
Serranus annularis	147
Serranus baldwini	110
Serranus tabacarius	136
Serranus tigrinus	49
undetermined	164
GRAMMIDAE	
Gramma loreto	17
Gramma melacara	7
APOGONIDAE	
Apogon townsendi	136
MALACANTHIDAE	
Malacanthus plumeri	52
CARANGIDAE	
Caranx bartholomaei	110
Caranx crysos	104
Caranx hippos	126
Caranx latus	56
Caranx ruber	22
Trachinotus falcatus	164
LUTJANIDAE	
Lutjanus sp.	119

Appendix I. (Continued).

FAMILY *Species*	**Rank**
Lutjanus analis	89
Lutjanus apodus	24
Lutjanus cyanopterus	104
Lutjanus griseus	30
Lutjanus jocu	41
Lutjanus mahogani	33
Lutjanus synagris	68
Ocyurus chrysurus	8
GERREIDAE	
Gerres cinereus	50
undetermined	89
HAEMULIDAE	
Anisotremus surinamensis	96
Anisotremus virginicus	94
Haemulon sp.	110
Haemulon album	45
Haemulon aurolineatum	35
Haemulon carbonarium	62
Haemulon chrysargyreum	47
Haemulon flavolineatum	20
Haemulon macrostomum	126
Haemulon parrai	126
Haemulon plumeri	19
Haemulon sciurus	11
INERMIIDAE	
Inermia vittata	76
SPARIDAE	
Calamus sp.	84
Calamus bajonado	113
Calamus calamus	86
SCIAENIDAE	
Equettus lanceolatus	136
MULLIDAE	
Mulloidichthys martinicus	42
Pseudupeneus maculatus	60
KYPHOSIDAE	
Kyphosus sp.	116
Kyphosus sectatrix	126
EPHIPPIDAE	
Chaetodipterus faber	99
CHAETODONTIDAE	
Chaetodon capistratus	29
Chaetodon ocellatus	64

Appendix I. (Continued).

FAMILY *Species*	**Rank**
Chaetodon striatus	70
POMACANTHIDAE	
Holacanthus sp.	164
Holacanthus ciliaris	96
Holacanthus tricolor	55
Pomacanthus arcuatus	65
Pomacanthus paru	89
POMACENTRIDAE	
Abudefduf saxatilis	18
Abudefduf taurus	147
Chromis cyaneus	2
Chromis insolatus	26
Chromis multilineatus	12
Chromis scotti	164
Microspathodon chyrsurus	27
Pomacentrus sp.	44
Pomacentrus diencaeus	31
Pomacentrus fuscus	16
Pomacentrus leucostictus	32
Pomacentrus partitus	5
Pomacentrus pictus	136
Pomacentrus planifrons	15
Pomacentrus variabilis	74
CIRRHITIDAE	
Amblycirrhitus pinos	147
LABRIDAE	
Bodianus rufus	77
Clepticus parrai	1
Halichoeres bivittatus	40
Halichoeres caudalis	126
Halichoeres cyanocephalus	39
Halichoeres garnoti	14
Halichoeres maculipinna	48
Halichoeres pictus	37
Halichoeres poeyi	164
Halichoeres radiatus	86
Lachnolaimus maximus	4
Thalassoma bifasciatum	164
SCARIDAE	
Scarus sp.	79
Scarus coelestinus	101
Scarus coeruleus	68
Scarus croicensis	6

Appendix I. (Continued).

FAMILY *Species*	**Rank**
Scarus guacamaia	164
Scarus taeniopterus	28
Scarus vetula	52
Sparisoma sp.	164
Sparisoma atomarium	84
Sparisoma aurofrenatum	23
Sparisoma chrysopterum	34
Sparisoma radians	74
Sparisoma rubripinne	46
Sparisoma viride	25
undetermined	58
SPHYRAENIDAE	
Sphyraena barracuda	92
OPISTOGNATHIDAE	
Opistignathus aurifrons	91
CLINIDAE	
Acanthemblemaria chaplini	136
Emblemaria sp.	147
Emblemaria pandionis	164
Hemiemblemaria simulus	147
Lucayablennius zingaro	164
Malacoctenus macropus	147
Malacoctenus triangulatus	164
BLENNIDAE	
Ophioblennius atlanticus	126
GOBIDAE	
Coryphopterus sp.	93
Coryphopterus dicrus	136
Coryphopterus glaucofraenum	79
Coryphopterus lipernes	164
Coryphopterus personatus	21
Gnatholepis thompsoni	62
Gobiosoma oceanops	63
undetermined	82
ACANTHURIDAE	
Acanthurus sp.	116
Acanthurus bahianus	13
Acanthurus chirurgus	42
Acanthurus coeruleus	9
SCOMBRIDAE	
Scomberomorus cavalla	113
Scomberomorus regalis	110

Appendix I. (Continued).

FAMILY *Species*	**Rank**
BOTHIDAE	
Bothus lunatus	147
BALISTIDAE	
Aluterus scriptus	119
Balistes capriscus	147
Balistes vetula	72
Catherhines pullus	99
Canthidermis sufflamen	104
Melichthys niger	54
Monacanthus tuckeri	164
undetermined	136
OSTRACIDAE	
Lactophrys bicaudalis	147
Lactophrys polygonia	164
Lactophrys triqueter	126
TETRAODONTIDAE	
Spheoroides spengleri	119
DIODONTIDAE	
Canthigaster rostrata	57
Diodon hystrix1	64