Comparison of Grouper Assemblages in Northern Areas of the Wider Caribbean: A Preliminary Assessment

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ABSTRACT

Groupers (Pisces: Serranidae) are important top-level predators in wider Caribbean, but have experienced significant exploitation, resulting in declines in abundance, size, spawning aggregations, and changes in species composition. Larger groupers are particularly vulnerable to intense fishing because of their longevity, slow growth, delayed reproduction, and aggregate spawning. Marine fishery reserves (MFR), areas permanently closed to consumptive use, offer a viable means to protect grouper resources. This study reports on fishery-independent surveys of groupers in four regions of the tropical western Atlantic during 1995 - 1997: Florida Keys, central Bahamas, southeastern Cuba, and Dominican Republic. The regions surveyed included two national parks and a national marine sanctuary, and were further categorized as: 1) intensively fished with little or no management for groupers (Cuba, Dominican Republic); 2) intensively fished with gear and effort limitations (Florida Keys); 3) lightly fished with some management (N. and S. Exuma Cays, Bahamas); and 4) a MFR closed to fishing since 1986 (Exuma Cays Land and Sea Park, Bahamas). From 10 - 20 strip transects (20 m x 5 m) were surveyed in shallow-water (1-20 m depth) hard-bottom habitats for grouper species composition, density, and size distribution. Nine grouper species (6 *Epinephelus* spp., 3 *Mycteroperca* spp.)

were documented among all regions. Areas in which groupers were partially or wholly protected from fishing had greater grouper diversity, density, and biomass, particularly for targeted species such as Nassau grouper (*E. striatus*). Classification of groupers by three size classes (small, intermediate, large) indicated a distinct gradient from areas with intense fishing to the MFR. In three of the regions affected by intense fishing, one of which has several grouper fishery regulations, grouper abundance and biomass were dominated by non-targeted species such as the graysby (*E. cruentatus*) and coney (*E. fulvus*). This second-order effect of fishing probably indicates competitive or predation. MFRs represent a viable means to protect grouper resources, alleviating the complications of enforcement and partially the need to gather fisheries dependent data. The ability of groupers to recover in certain regions may be deterred because of reduced larval recruitment from upstream, heavily fished sources.

KEY WORDS: Caribbean, grouper, Marine Fishery Reserve

INTRODUCTION

Groupers (Serranidae, Epinephilinae) are important top-level predators in coral reef ecosystems worldwide (Parrish, 1987). They are highly sedentary, living near the bottom in holes, caves, and crevices. Groupers occupy a variety of habitats over a wide depth range (2 - 50+ m) and feed primarily upon fishes and crustaceans (Nagelkerken, 1981; Sluka, 1995; Sluka and Sullivan, 1996a). Many species can attain very large sizes (> 90 cm total length, TL). Moderate- to large-size species exhibit the characteristics of slow growth to a large size, delayed reproduction, long life-span, reduced spawning period, and possible sex reversal (protogyny) (Sadovy, 1994). In addition, a few species exhibit aggregate spawning behavior (Smith, 1972; Manooch, 1987; Shapiro, 1987).

Groupers are prized food fishes in both recreational and commercial fisheries (Carter *et al.*, 1994; Bohnsack *et al.*, 1994), but have experienced significant declines (abundance, size, landings, CPUE) due to severe exploitation in the wider Caribbean (Gobert, 1994; Huntsman *et al.*, 1994; Sadovy, 1994). In many instances, overfishing of spawning aggregations has been the cause of decline (Beets and Friedlander, 1992; Carter *et al.*, 1994; Aguilar-Perera and Aguilar-Davila, 1996; Luckhurst, 1996). Nassau grouper (*Epinephelus striatus*) and other large, targeted species are particularly vulnerable to fishing, even at moderate levels, because of their life history characteristics (Olsen and LaPlace, 1978; Huntsman and Schaaf, 1994; Sadovy *et al.*, 1994; Sadovy and Colin, 1995). Intense fishing pressure tends to decrease the abundance and average size of fish (Ferry and Kohler, 1987; PDT, 1990; Beets and Friedlander, 1992), but can additionally result in the decline of spawning aggregations (Carter *et al.*, 1994; Aguilar-Perera and Aguilar-Davila, 1996), changes in species composition

(Goeden, 1982), declines in species richness (Russ and Alcala, 1989), and increases in the absolute and relative abundance of non-targeted species (Bohnsack, 1982; Sluka and Sullivan, 1996b). Conventional management of grouper fisheries (i.e. management of catch or effort) has not prevented stocks from being overfishing (Huntsman *et al.*, 1994; Bohnsack et al., 1994), likely due to a combination of inadequate enforcement, lack of biological knowledge, and socioeconomic factors (Sadovy, 1994). For example, the Nassau grouper is now federally protected in the United States (Bohnsack *et al.*, 1994) and has declined to such a degree in the U.S. Virgin Islands and Puerto Rico due possibly to overfishing of spawning aggregations that it is now considered economically extinct (Sadovy, 1994).

Recent evidence has shown that protection of groupers in marine fishery reserves (MFR) results in more abundant and larger individuals compared to fished areas (Russ, 1985; PDT, 1990; Russ *et al.*, 1992; Watson and Ormond, 1994). The main goal of this study was to make a preliminary assessment of grouper resources through fishery-independent surveys in northern areas of the wider Caribbean. The specific objectives were to: 1) survey regions differing in fishing intensity and fisheries management activity; 2) compare grouper species composition, density, and biomass among regions; and 3) compare density and biomass inside and outside of MFR. In addition, this study presents evidence for second-order effects of fishing and discusses the potential for groupers in certain regions to recover. Although juvenile and adult groupers can differ in their relative abundance among types of coral reefs and can have specific habitat preferences (Nagelkerken, 1979, 1981; Shpigel and Fishelson, 1989), analyses of habitat factors as they pertain to the study regions are presented elsewhere (Sluka, 1995; Sluka *et al.*, 1996a,b; Sluka and Sullivan, 1996a,b).

MATERIALS AND METHODS

Study areas

Four geographic areas of the northern wider Caribbean were surveyed for grouper species composition, density and size during a series of field surveys from 1995-97 (Figure 1). Several sites (n = 70) and hard-bottom habitat types were surveyed over a 1 to 20 m depth range (Table 1). Descriptions of reef and hard-bottom types surveyed in these regions are presented elsewhere (Chiappone and Sullivan, 1997; Chiappone *et al.*, 1996; Sluka *et al.*, 1996b; Vega *et al.*, 1996). In Guantanamo Bay, Cuba, grouper surveys were conducted at 8 high-relief spur and groove reefs during July - August 1995. In the southeastern Dominican Republic, seven sites representing four main habitat types were surveyed from 10 - 20 m depth during April 1997.

Table 1. Regions of the northern wider Caribbean surveyed for groupers during 1995 - 1997.

Region	No. sites	No. transects	Hard-bottom types	Depth (m)
Guantanamo Bay, Cuba	8	112	High-relief spur and groove	5-14
Dominican Republic	7	140	Reef ridge	10-12
			Low-relief spur and groove	15-20
			Deep rocky outcrops	15-17
			Low-relief hard-bottom	15-18
Florida Keys	8	156	High-relief spur and groove	3-9
			Relict reef flat	4-10
Exuma Cays, Bahamas	55	550	Channel reef	2-11
			Fringing reef	1-15
			Low-relief hard-bottom	3-13

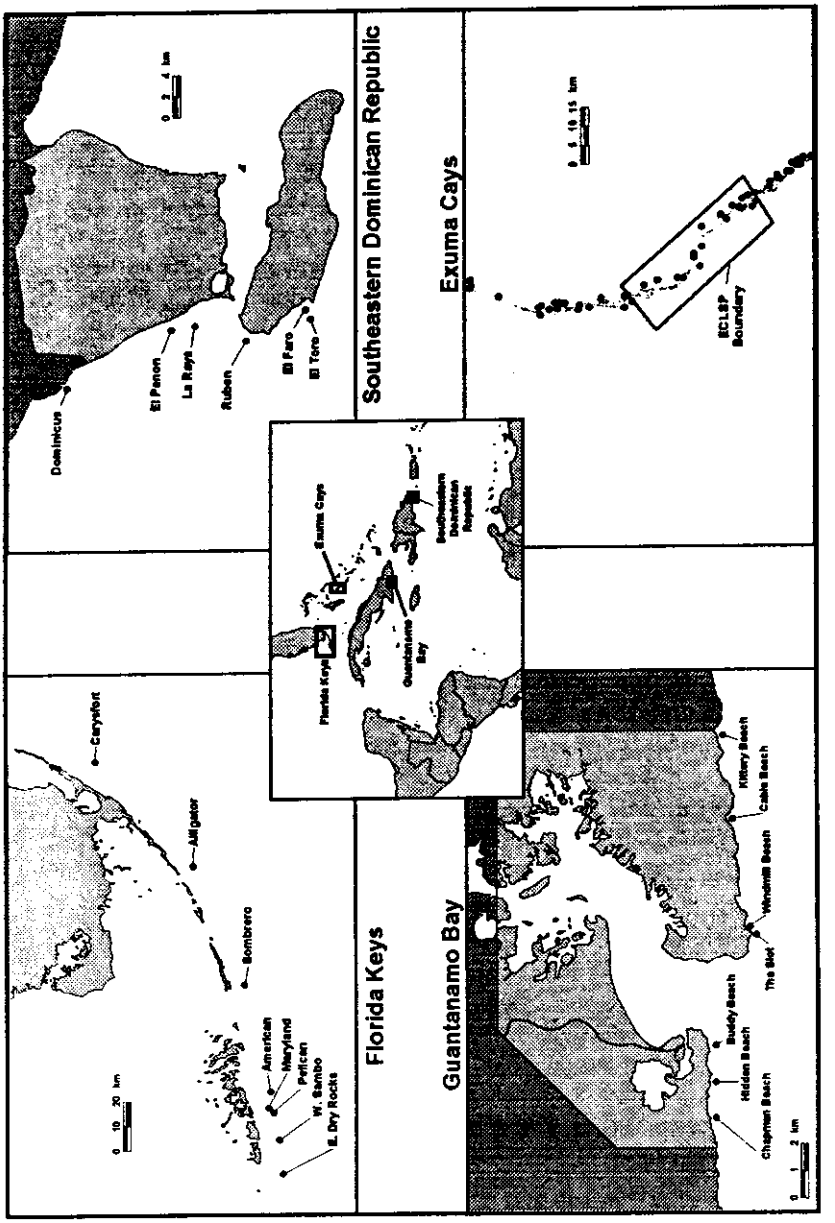

Figure 1. Map of the northern wider Caribbean and grouper survey regions in the Florida Keys, Bahamas, southeastern Cuba, and southeastern Dominican Republic.

Eight platform margin reefs were surveyed in the Florida Keys (3 - 10 m) during June - August 1995. Fifty-five reef and low-relief hard-bottom sites (1 - 15 m) were surveyed in the Exuma Cays, central Bahamas, during October - November 1995.

For data analysis and statistical computations, the four areas were further classified according to relative fishing pressure and the status of grouper fishery regulations (Table 2). Two of the regions were classified as intensively fished with little or no management. In southeastern Cuba, reefs were surveyed within the boundaries of the U.S. Naval Base at Guantanamo Bay. Destructive fishing practices are prohibited, however, there are no fishing restrictions for groupers, such as daily quotas, minimum size, or area closures. Grouper fishing is mainly for recreational purposes; the main fishing methods used are spearguns and hook-and-line.

In the Dominican Republic, five of the seven sites surveyed are in a national park, Parque Nacional del Este. Established in 1975, Parque Nacional del Este is the second largest protected area in the Dominican Republic, comprising over 43,000 ha of terrestrial habitats and an additional 12,000 ha of shallow-water (< 30 m) marine habitats. There are four small villages and towns within and adjacent to the park where fishermen originate; most fishing is artisanal in nature. Fishing methods include hook-and-line, spears, free diving, hookah, and traps. The majority (> 80%) of fishing is conducted using hook-and-line and spears. Organisms most targeted include Scaridae, Balistidae, *Ocyurus chrysurus*, and *Epinephelus guttatus*. Previous fishery-independent surveys of target organisms in the park are limited (Towle *et al.*, 1973; Gauge and Arnemann, 1982; Williams *et al.*, 1983). In August, 1973, a reconnaissance survey of the park was carried out to describe major habitats and make recommendations for resource management (Towle *et al.*, 1973). They reported 25 years ago that conch, lobster, and finfish resources were severely depleted in many areas of the park, particularly due to spear-fishing. The most immediate potential management difficulty in the park is the high level of past and present use of fisheries resources.

The Florida Keys region was classified as intensively fished with relatively intensive management. The Florida Keys are situated at the northern edge of the distribution of many tropical groupers, however, the catch composition is similar to the Caribbean (Bohnsack *et al.*, 1994). All surveyed reefs are located in the Florida Keys National Marine Sanctuary, a 9,515 km^2 protected area established in 1990. A commercial fishery for groupers has existed in the Florida Keys since the mid-1800s. In the larger, federally managed U.S. South Atlantic, 14 species are considered important in the commercial and recreational fisheries (Huntsman *et al.*, 1994).

Table 2. Grouper fishery and management characteristics of study regions in the northern wider Caribbean. N/A: not applicable. MFR: marine fishery reserve.

Classification/region	Gear	Management		
		Bag limit	Size limit	MFR
Heavily fished, little mgmt.				
Guantanamo Bay, Cuba	Spears, hook-and-line	N/A	N/A	N/A
Dominican Republic	Spears, traps, hook-and-line	N/A	N/A	N/A
Heavily fished, high mgmt.				
Florida Keys	Spears, hook-and-line	X	X	
Lightly fished, moderate mgmt.				
N. Exuma Cays, Bahamas	Spears, traps, hook-and-line		X	
S. Exuma Cays, Bahamas	Spears, traps, hook-and-line		X	
No fishing, high mgmt.				
Exuma Cays Land & Sea Park	N/A			X

Fisheries dependent data suggests that landings and catch composition have changed dramatically as a result of increasing commercial and recreational fishing (Bohnsack *et al.*, 1994). Landings declined by 55% from 1977 to 1992. Fishing methods include primarily spear-guns and hook-and-line in the sanctuary. Targeted species in the Florida Keys primarily include black grouper (*Mycteroperca bonaci*) and red grouper (*Epinephelus morio*). Gag (*M. microlepis*) is the dominant target species northeast and west of the Florida Keys (Sadovy, 1994). *M. bonaci* is not considered overfished according to the South Atlantic Fisheries Management Council, however, four other species are considered overfished based on spawning stock per recruitment ratio (Huntsman *et al.*, 1994). Carysfort Reef (Figure 1) has been protected from spear-fishing and trap fishing since 1975. Fishing for Nassau grouper (*E. striatus*) and jewfish (*E. itajara*) has been banned since the mid-1980s due to overfishing. There are recreational and commercial catch quotas and minimum size regulations for several species currently in effect.

In the Exuma Cays, central Bahamas, 55 sites representing three shallow-water (1 - 15 m) hard-bottom habitat types were surveyed during October - November 1995 along 90 km of the island archipelago between the Great Bahama Bank and Exuma Sound (Sluka *et al.*, 1996b). Three separate areas were surveyed to evaluate the composition, density and size of groupers: Northern Exuma Cays, Exuma Cays Land and Sea Park, and Southern Exuma Cays. The Northern and Southern Exuma Cays were classified as lightly fished with moderate management. Artisanal and commercial fishing primarily targets Nassau grouper (*Epinephelus striatus*); this species is the third most important commercial fishery (behind spiny lobster and queen conch) and most important finfish species in the country. Most of the landings are generated from the fishing of spawning aggregations during December - February at several locations in the country. Only two percent of the roughly 17,619 mt annual catch originates from the Exuma Cays, however, this does not include individuals caught for local consumption (V. Deleveaux, Bahamas Department of Fisheries, personal communication). Other large species of grouper (e.g., *Mycteroperca* spp.) are not generally targeted. Fishing methods in the Northern Exumas include spearguns, traps and hook-and-line, while spearguns and hook-and-line are mainly used in the Southern Exumas.

Between the Northern and Southern Exuma Cays regions lies the Exuma Cays Land and Sea Park (ECLSP), a marine fishery reserve (MFR). The ECLSP was established by the Bahamas Government in 1958. The following year, the Bahamas National Trust (BNT), a non-governmental organization, was created by an Act of Parliament and mandated with the responsibilities and powers to manage the ECLSP and any future national parks. The ECLSP encompasses a 35 km long section of the Exuma Cays, covering an area of 456 km^2. Initially,

limited fishing was allowed, but by the 1980s, fishing pressure in the park had increased dramatically such that the BNT changed park by-laws in 1986 to make the entire area a no-take zone. Removal of any live or dead organism on the land or sea is prohibited without a permit. A warden has been on-site since 1989. Presently, there is one warden in the park who is assisted by a volunteer support fleet. The park is subjected to some level of poaching, reflected in the decreased abundance and biomass of Nassau grouper away from the ranger station (Sluka *et al.*, 1996b).

Grouper surveys

This study employed visual censuses of groupers in line transects, a practical way to survey species such as groupers, which are often associated with caves, crevices, and overhangs (Bell *et al.*, 1984). In each region, 10 - 20 transects measuring 20 m x 5 m in area were haphazardly placed in hard-bottom habitats and surveyed for grouper species composition, number, and size. The width of the transect was visually estimated. Observers were trained to accurately estimate the width of transects by swimming the length of a transect and placing construction flags at the estimated distance of 2.5 m out on each side of the line. The average estimated distance was compared to the desired estimate and biases were made known to the observers. Observers were also trained to estimate the length of fish to the nearest cm by swimming past a series of fish models and visually estimating their sizes (Bell *et al.*, 1984). Results were compared to known lengths for each model and the individual biases were made known to each observer. In the Exuma Cays, Bahamas, 10 transects per site were surveyed based on desired precision levels and pilot studies (Sluka *et al.*, 1994, 1997). In all other regions, generally 20 transects per site were surveyed due to the apparently low density of groupers, particularly larger species. Data presented herein represent a total sample size of 70 sites and 958 transects.

Data analysis

This preliminary assessment compares the density, relative abundance, biomass, and relative biomass of groupers among study regions. Mean density (no./100 m^2) and biomass (g/100 m^2) of species were computed for each region based upon mean values from sites. Length values for groupers were converted to biomass using known length-weight relationships (Thompson and Munro, 1978; Manooch and Mason, 1987; Claro and Garcia-Arteaga, 1994; Potts and Manooch, 1995; Sadovy and Colin, 1995). Non-parametric analysis of variance (Kruskal-Wallis test) was used to test for significant differences in mean density and biomass of species by region (Zar, 1996).

Relative abundance and biomass (% total) measures were computed based on each species contribution to the total in each region. Similarity of study regions

based on the relative abundance and biomass of species was computed using the Percent Similarity Index (Pielou, 1977). Pair-wise comparisons were made among regions and used to construct a dendrogram from a group-average sorting strategy.

Comparisons were also made among regions according to the relative abundance and biomass of life history groups or size categories of groupers. Grouper species can be divided into three general categories based on growth histories: small, intermediate, and large (Shapiro, 1987; Sluka and Sullivan, 1996b). Small species are graysby (*Epinephelus cruentatus*) and coney (*E. fulvus*); they tend to remain relatively small (maximum length < 41 cm) and reach sexual maturity between 16 cm and 25 cm TL (Thompson and Munro, 1978; Nagelkerken, 1979). Intermediate-size species are red hind (*E. guttatus*) and rock hind (*E. adscensionis*); they attain a maximum size generally between 41 and 60 cm TL (Thompson and Munro, 1978; Potts and Manooch, 1995). Large species are Nassau grouper (*E. striatus*) and *Mycteroperca* spp. These species sexually mature between 42 cm and 50 cm TL (Shapiro, 1987; Sadovy and Colin, 1995), may grow to over 90 cm TL, and attain a maximum size generally greater than 60 cm TL (Thompson and Munro, 1978; Manooch, 1987; Manooch and Mason, 1987).

RESULTS

Species composition and density

Nine grouper species were identified in transect surveys throughout the study area (Table 3). In two of the intensively fished regions, southeastern Cuba and the Dominican Republic, only 3 - 5 species were identified, while in the lightly fished and marine reserve regions, 7 - 9 species were observed. Mean grouper densities (no./100 m^2) exhibited significant variation among regions for most species: *Epinephelus cruentatus* ($H = 34.04$, $df = 5$, $p < 0.001$), *E. fulvus* ($H = 29.71$, $df = 5$, $p < 0.001$), *E. striatus* ($H = 38.41$, $df = 5$, $p < 0.001$), *Mycteroperca bonaci* ($H = 19.32$, $df = 5$, $p < 0.01$), *M. tigris* ($H = 15.89$, $df = 5$, $p < 0.01$), and *M. venenosa* ($H = 11.85$, $df = 5$, $p < 0.05$). Non-targeted species, such as *E. cruentatus* and *E. coney*, were significantly more abundant in intensively fished regions, while larger groupers were significantly more abundant in lightly fished and regions and the MFR. This was particularly the case *E. striatus*, which was six times more abundant in the MFR than in the Florida Keys, as well two to 12 times greater than in the northern and southern Exumas, respectively. Even in the lightly fished regions of the Exuma Cays, significant differences inside and outside of the MFR were evident. In the northern Exuma Cays, *E. cruentatus*, *E. fulvus*, and *E. guttatus* were dominant, comprising over 80% ($n = 318$) of the groupers recorded.

Table 3. Grand mean (1 SD) in grouper density (no./100 m^2) in northern areas of the wider Caribbean. + = species observed in study area but not surveyed in transects.

Species	Cuba	DR	Florida Keys	N. Exumas	ECLSP	S. Exumas
E. adscensionis		0.04 (0.07)	0.04 (0.19)	0.01 (0.04)	0.04 (0.14)	0.01 (0.12)
E. cruentatus	2.30 (1.30)	0.95 (0.49)	0.97 (1.10)	0.60 (0.87)	0.27 (0.55)	0.16 (0.49)
E. fulvus	0.63 (0.87)	0.35 (0.41)	0.01 (0.08)	0.44 (0.87)	0.52 (0.83)	1.30 (1.35)
E. guttatus		0.08 (0.11)	0.04 (0.21)	0.20 (0.43)	0.14 (0.41)	0.13 (0.37)
E. itajara				+		
E. striatus	+	+	0.01 (0.11)	0.20 (0.43)	0.35 (0.55)	0.16 (0.37)
M. bonaci			0.04 (0.21)	0.01 (0.14)	0.01 (0.14)	
M. tigris			0.02 (0.14)	0.06 (0.29)	0.12 (0.28)	0.01 (0.37)
M. venenosa				0.01 (0.14)	0.05 (0.14)	0.02 (0.12)

These same species accounted for over 88% (n=268) of the individuals observed south of the MFR. In contrast, larger species of grouper, particularly *E. striatus*, represented a greater number of the groupers observed inside the MFR (23.5%) than in the northern (13.5%) or southern Exumas (9.0%).

The relative abundance of grouper species indicated that intensively fished regions were dominated (> 85% of total density) by smaller species (*Epinephelus cruentatus* and *E. fulvus*), while both non-targeted and targeted species were co-dominant in lightly fished regions and the MFR (Figure 2). In the MFR, *E. striatus* and *Mycteroperca* spp. comprised over 30 percent of the groupers observed. Cluster analysis of the relative abundance of species indicated separation of regions into two main categories: intensively fished and lightly fished (Figure 3). Furthermore, intensively fished regions with little or no management were most similar (88%).

Biomass

Mean grouper biomass exhibited a pattern similar to density among regions (Table 4). Mean grouper biomass (g/100 m^2) exhibited significant variation among regions for most species: *Epinephelus cruentatus* ($H = 30.83$, $df = 5$, $p < 0.001$), *E. fulvus* ($H = 27.45$, $df = 5$, $p < 0.001$), *E. guttatus* ($H = 12.86$, $df = 5$, $p < 0.05$), *E. striatus* ($H = 38.07$, $df = 5$, $p < 0.001$), *Mycteroperca bonaci* ($H = 18.13$, $df = 5$, $p < 0.01$), *M. tigris* ($H = 16.28$, $df = 5$, $p < 0.01$), and *M. venenosa* ($H = 11.44$, $df = 5$, $p < 0.05$). Non-targeted species, such as *E. cruentatus* and *E. coney*, generally had greater biomass in intensively fished regions, while larger groupers had greater biomass in lightly fished regions and the MFR. This was especially true for *E. striatus*, whose biomass was over 30 times greater in the MFR than in the Florida Keys, as well three to four times greater than in the northern and southern Exumas, respectively. Even in the lightly fished regions of the Exuma Cays, significant differences inside and outside of the MFR were noted. In the northern Exuma Cays, *E. cruentatus*, *E. fulvus*, and *E. guttatus* were dominant, comprising over 80% ($n = 318$) of the groupers recorded. These same species accounted for over 88% ($n = 268$) of the individuals observed south of the MFR. In contrast, larger species of grouper, particularly *E. striatus*, represented a greater number of the groupers observed in the MFR (23.5%) than in the northern (13.5%) and southern Exumas (9.0%).

The relative contribution of species to the total grouper biomass illustrated that intensively fished regions were dominated (50 - 100%) by smaller species (*Epinephelus cruentatus* and *E. fulvus*), while lightly fished regions (50 - 56%) and the MFR (86%) were dominated by larger groupers (Figure 4). The Florida Keys exhibited intermediate relative biomass values for larger groupers (40%). Cluster analysis of the relative biomass of species indicated separation of regions into two main categories: intensively fished and lightly fished (Figure 5).

Futthermore, intensively fished regions with little or no management were highly (75%) similar.

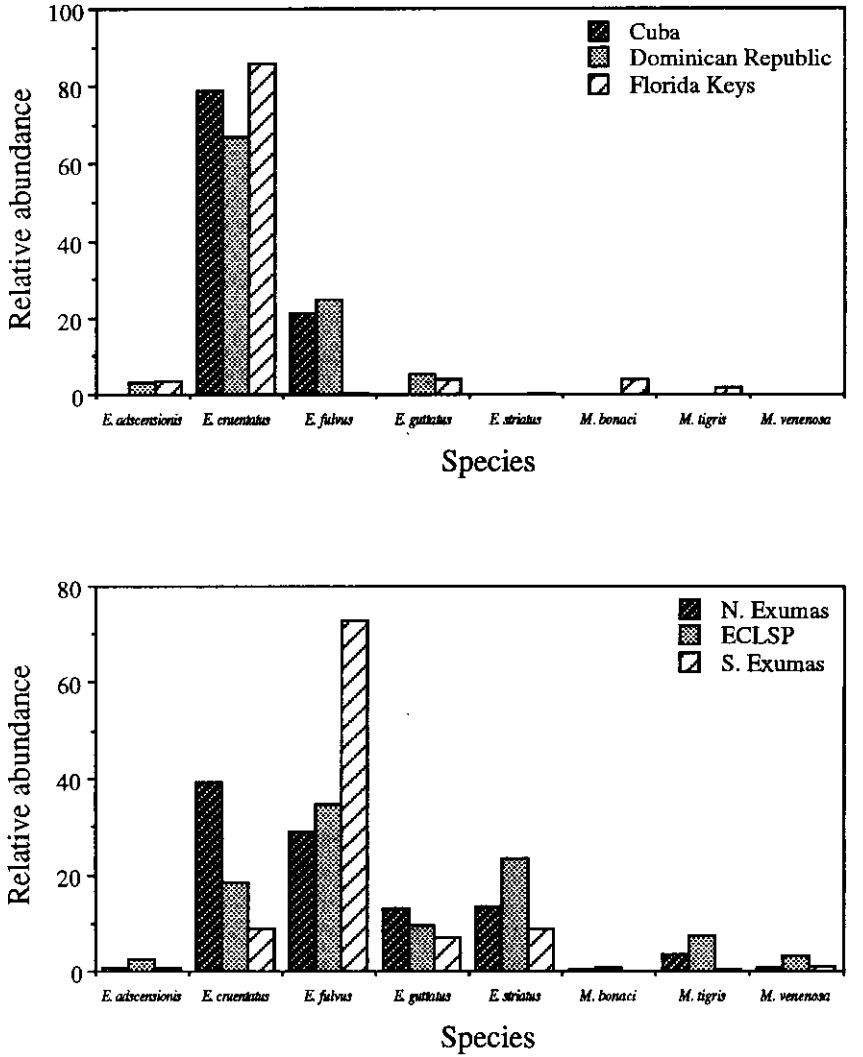

Figure 2. Relative abundance (% of total) of grouper species in intensively fished (top) and lightly fished (bottom) regions.

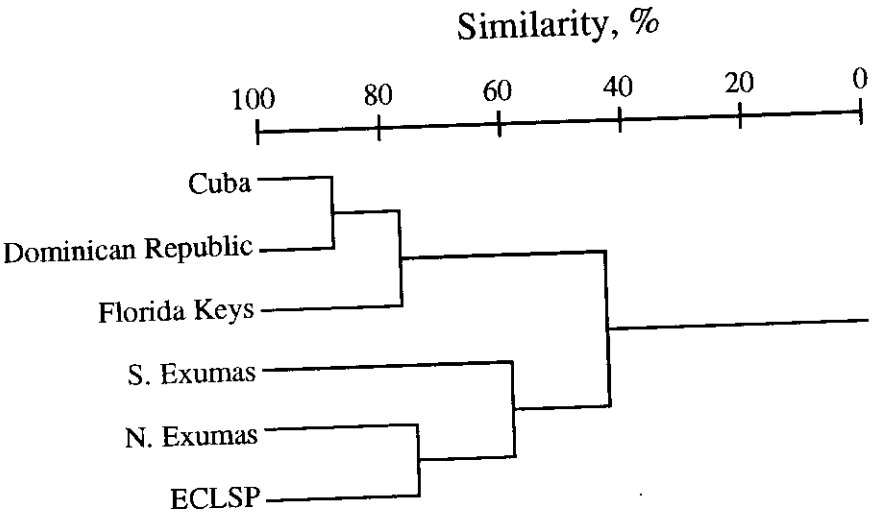

Figure 3. Classification of regions based on the relative abundance of groupers, using group-average sorting of percent similarity values.

Life history

Analysis of the relative abundance and biomass of 3 grouper size categories (small, intermediate, giant) revealed distinct patterns among regions (Figure 6). From intensively fished regions to the MFR, the relative abundance and biomass of small species decreased, while these same metrics increased for large species. In intensively fished regions, smaller groupers comprised 86% to 100% of the groupers surveyed. In lightly fished and marine fishery reserve regions, however, smaller groupers comprised 53% to 82% of the total grouper density. Large groupers only accounted for 0% to 6.2% of the total groupers in intensively fished regions, but 10% to 35% in lightly fished regions and the MFR. Differences among regions were as evident by relative biomass. In Cuba and the Dominican Republic, 75% to 100% of the grouper biomass was comprised of small species. In contrast, 52% to 88% of the total biomass in lightly fished regions was represented by large species (*Epinephelus striatus* and *Mycteroperca* spp.).

Table 4. Grand mean (1 SD) in grouper biomass (g/100 m^2) in northern areas of the wider Caribbean.

Species	Cuba	DR	Florida Keys	N. Exumas	ECLSP	S. Exumas
E. adscensionis		29.7 (66.7)	11.5 (77.4)	5.2 (16.4)	13.6 (40.8)	6.9 (18.5)
E. cruentatus	136.0 (63.0)	96.1 (73.9)	103.6 (136.6)	40.3 (41.6)	18.2 (18.5)	21.9 (40.0)
E. fulvus	71.9 (117.1)	45.5 (54.8)	0.7 (8.6)	54.5 (54.7)	54.7 (44.8)	143.4 (80.4)
E. guttatus		18.0 (24.6)	8.8 (45.7)	71.7 (66.8)	40.5 (67.0)	31.2 (40.3)
E. striatus			15.7 (156.4)	166.5 (213.4)	495.7 (370.2)	118.0 (145.7)
M. bonaci			49.5 (340.6)	5.7 (26.1)	121.4 (365.0)	
M. tigris			21.2 (206.7)	28.8 (59.8)	101.8 (142.0)	6.7 (26.1)
M. venenosa				17.5 (56.2)	158.5 (370.6)	94.3 (276.3)

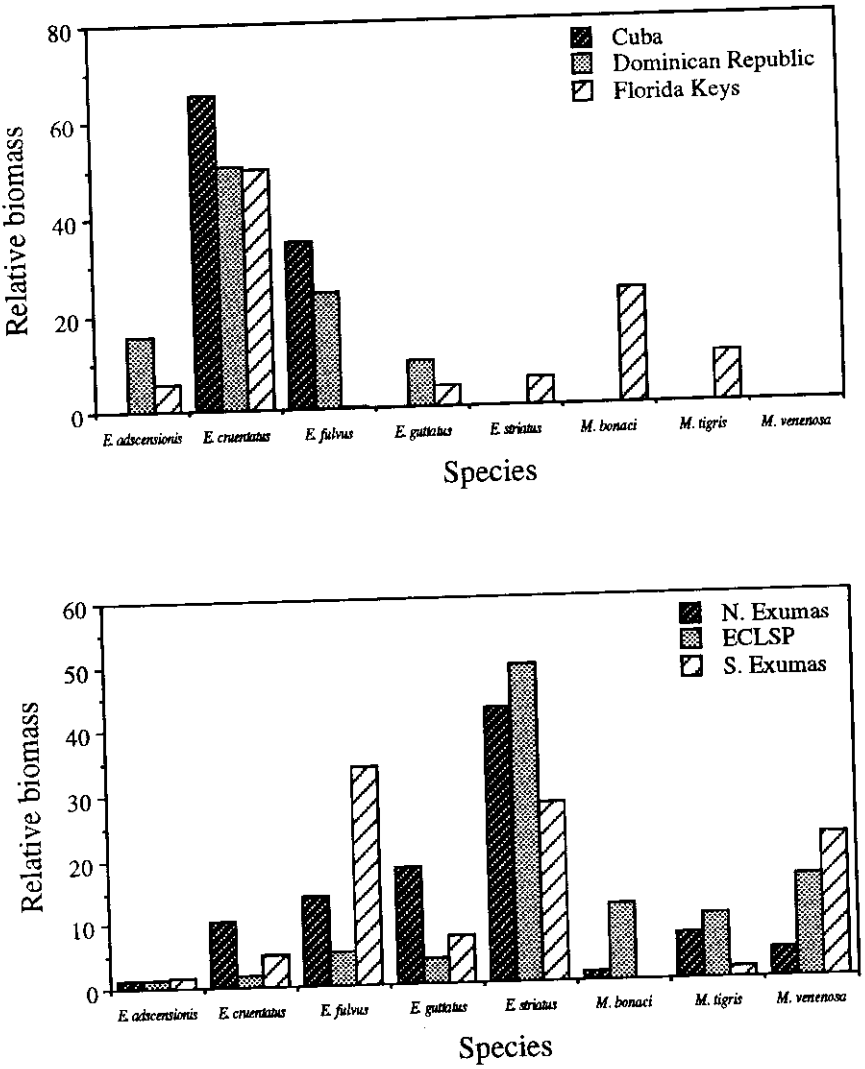

Figure 4. Relative biomass (% of total) of grouper species in intensively fished (top) and lightly fished (bottom) regions.

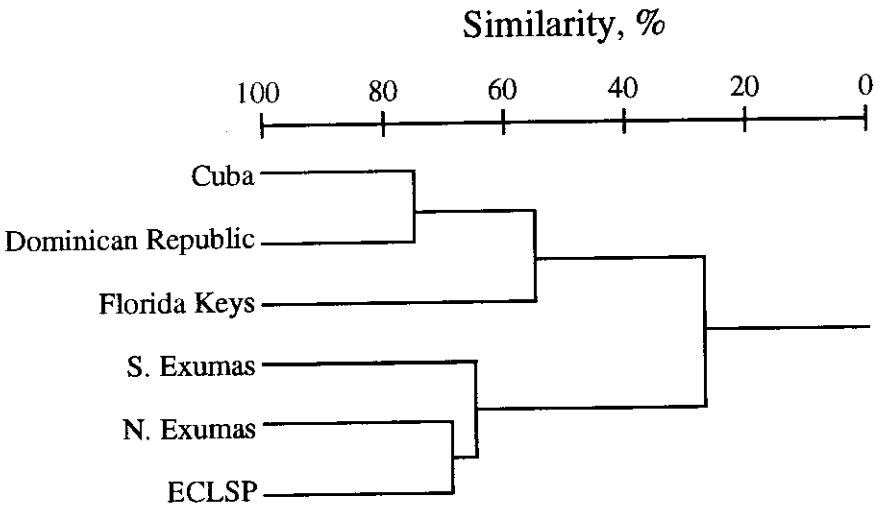

Figure 5. Classification of survey regions based on the relative biomass of groupers, using group-average sorting of percent similarity values.

DISCUSSION

This preliminary assessment of grouper assemblages in northern areas of the wider Caribbean has shown greater absolute and relative density and biomass of larger groupers in lightly fished regions and a marine fishery reserve (MFR) than in heavily fished regions with intense to little or no fisheries management. Intensively fished regions generally exhibited lower species diversity and a dominance by small groupers. From the intensively fished regions to the MFR, the relative abundance and biomass of small grouper species decreased significantly (r_s = -.971, $p < 0.01$), while the relative abundance and biomass of large groupers increased significantly (r_s = .933, $p < 0.01$). The increase in smaller, non-targeted species in intensively fished regions potentially reflects a second-order effect of fishing pressure (mediated by changes in competition or predation). Despite some biogeographic differences in grouper species composition among regions (Sluka *et al.*, 1994; Huntsman *et al.*, 1994), analysis of grouper composition by growth history (size class) revealed dramatic patterns in abundance and biomass among according to relative protection.

Several reviews of marine fishery reserves (MFRs) have recently been completed and highlight the utility of such areas to conserve fisheries resources,

as well as to serve as one potential strategy in a mixed fisheries management scheme (PDT, 1990; Roberts and Polunin, 1991; Rowley, 1994).

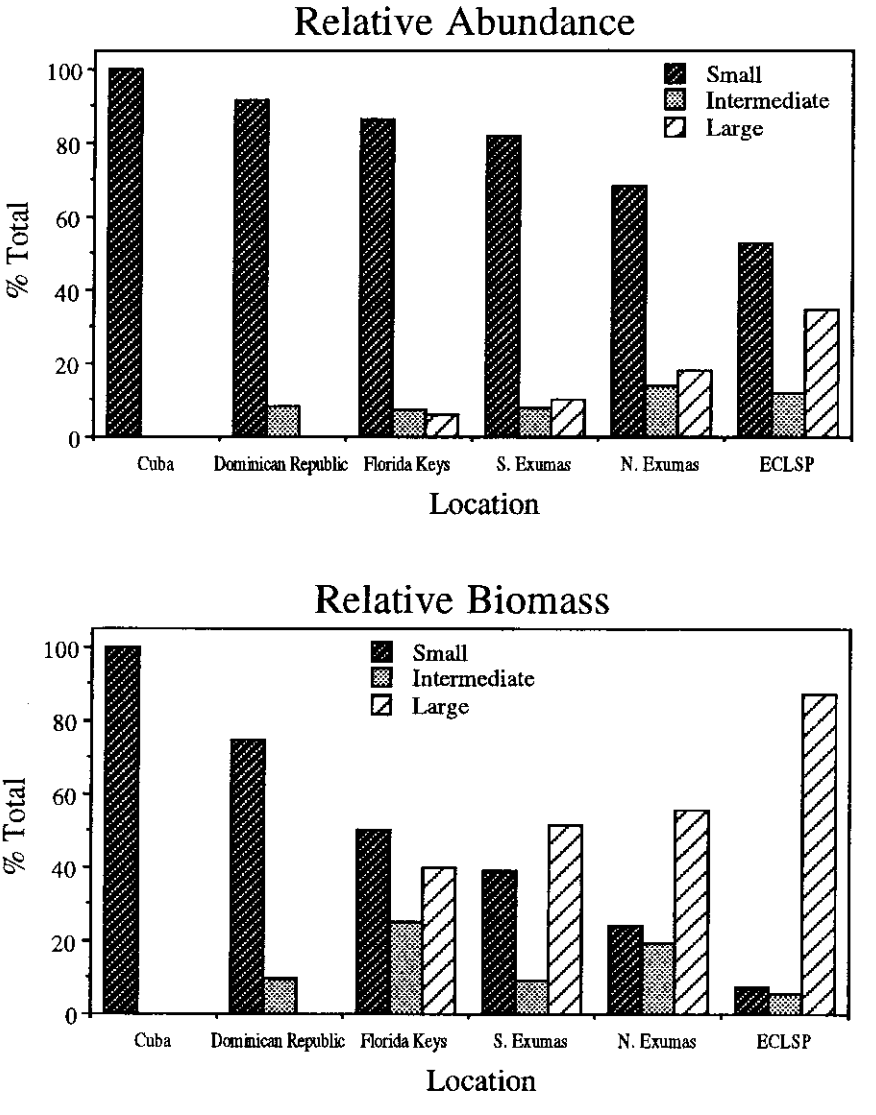

Figure 6. Relative abundance and biomass of groupers based on size category: Small = *E. cruentatus* and *E. fulvus*; Intermediate = *E. adscensionis* and *E. guttatus*; Large = *E. striatus*, *M. bonaci*, *M. tigris* and *M. venenosa*.

Marine fishery reserves result in a higher abundance and larger commercial species than in fished areas (Russ, 1985; Alcala, 1988; Russ and Alcala, 1989; Polunin and Roberts, 1993; Watson and Ormond, 1994). They may also result in increased larval supply and adult emigration to fished areas (PDT, 1990; Attwood and Bennett, 1994). There is also one reported case of an increase in fish yield outside the reserve due to the presence of the reserve (Alcala, 1988; Russ and Alcala, 1989). Reserves may also increase species richness (Russ and Alcala, 1989; this study) and increase economic gain (Van't Hof, 1985). This study has clearly shown that protection of groupers resources within MFRs resulted in greater species and higher density and biomass of large species, even in relatively shallow water (< 20 m). Even within the lightly fished region of the Exuma Cays, Bahamas, comparison inside and outside of the MFR indicated greater density, biomass, and estimated reproductive output of targeted species, particularly Nassau grouper (Sluka *et al.*, 1997). Moreover, it is likely that this MFR is an important source of larvae to the northern Exuma Cays (Sluka et al., 1996b), based on circulation patterns and the possible presence of a spawning aggregation (Colin, 1995), as well as biomass through adult emigration (Sluka *et al.*, 1997).

That relatively intensive fisheries management in the Florida Keys has not prevented the apparent decline (Bohnsack *et al.*, 1994; Sadovy, 1994) of shallow-water grouper assemblages is cause for concern. Despite intensive management in the U.S., perceptions by fishermen are that grouper populations have continued to decline in number, mean size, and age (Huntsman *et al.*, 1994). It is apparent that size limits along do not prevent the removal of the largest groupers, and that significant mortality of smaller individuals will likely occur. Given that fisheries dependent sampling and enforcement of traditional regulations (effort, catch) is time-consuming, expensive, and logistically difficult, MFRs, because they are likely to be easier to enforce, offer a viable alternative to traditional fisheries management to conserve critical spawning stock biomass and enhancement of yields in adjacent areas (PDT, 1990; Russ and Alcala, 1992).

This study has shown that intensive fishing of shallow-water grouper resources resulted in lower numbers of species, lower density and biomass of larger species, and differences in species composition and dominance patterns. In two of the regions, no larger species were found in over 100 transects surveyed. These results echo the status of many intensively fished tropical regions (Russ and Alcala, 1989; Gobert, 1990; Luckhurst, 1996. In many instances, grouper fishing is concentrated during the formation of spawning aggregations (Carter *et al.*, 1994; Aguila-Perera and Aguila-Davila, 1996). Intense fishing of these aggregations is thought to have potentially severe detrimental effects on future fishery yields (Olsen and LaPlace, 1978). Clearly the protection of spawning

aggregations is necessary to ensure the long-term viability of grouper populations (Beets and Friedlander, 1992; Sadovy, 1994).

The increase in absolute and relative abundance and biomass of non-targeted species in intensively fished regions represents a potentially second-order effect of fishing, mediated by changes in competition or predation (Bohnsack, 1982; Goeden, 1982; Jennings and Polunin, 1996). In other areas, removal of piscivores and invertivores resulted in predation release on invertebrates, in turn causing changes in benthic community structure and bioerosion rates (Watson and Ormond, 1994). The dominance of grouper assemblages by small species is characteristic of several Caribbean regions presently (Gobert, 1990; Beets and Friedlander, 1992; Luckhurst, 1996), however, the ecological changes brought about by changes in species composition and relative abundance are in need of further study.

The recovery potential of intensively fished systems will be a function of the status of stocks, the timing of fisheries decline, life history characteristics of species, availability of recruits to replenish fished areas, socio-economic factors, political will, and the perception of a 'natural' state. Few empirical data are available on recovery of fished regions after closure (Bohnsack, 1982; Russ and Alcala, 1989; Russ and Alcala, 1992). In the Florida Keys, Bohnsack (1982) reported that, after a spear-fishing ban in 1980, total predator abundance increased exponentially in the first two years of protection. Russ and Alcala (1992) documented significant positive linear correlations of mean density of large predators with years (8 - 10) of reserve protection in the Philippines. The pattern of mean biomass increase was more curvilinear, where a slow increase was observed in three to five years, followed by an increasing rate over the next 4 years. In the southeastern Dominican Republic, the recovery potential is particularly low, given that this area is down-current of the heavily fished eastern Caribbean (Beets and Friedlander, 1992; Sadovy, 1994). In the Florida Keys, MFRs may provide the only mechanism to evaluate fisheries resources in a relatively protected state, in order to evaluate the impacts of exploitation. Even in lightly fished regions such as the Bahamas, systems of MFRs established according to circulation patterns (i.e. sources, sinks, sources/sinks), as well as specific protection of existing spawning aggregations, may represent the most reliable means to ensure the viability of grouper populations.

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