# The Reef Fish Assemblage of Bonaire Marine Park: An Analysis of REEF Fish Survey Data

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ABSTRACT

The REEF/TNC Fish Survey Project is a volunteer fish monitoring program developed by the Reef Environmental Education Foundation (REEF) with support from The Nature Conservancy (TNC). REEF volunteers collect fish distribution and log scale abundance data for the project using a standardized visual method. These data are housed in a publicly accessible database on REEF's Website (http://www.reef.org). To date, the REEF database contains over 19,000 surveys from approximately 1,800 sites in the tropical western Atlantic region. The standardized census method provides a consistency in data collection applied over a wide geographic range. Such a database represents a valuable tool for marine resource managers. REEF data are currently being used by a number of marine parks and resource agencies for assessment and long-term monitoring, including the Bonaire Marine Park (BMP; Bonaire, Netherlands Antilles). Between December 1993 and July 1999, approximately 2,000 fish surveys have been completed by REEF volunteers on the reefs of Bonaire and Klein Bonaire. From these data, a total of 362 species were reported from 77 sites surveyed, making Bonaire one of the most species rich locations in REEF's database. Similarity and ordination analysis on a sub-set of sites indicated that fish assemblages on Klein Bonaire were distinct from those on Bonaire. Sites within the two Bonaire research reserves appeared distinct from other Bonaire sites. This paper provides the most comprehensive species list to date for the BMP. In addition, this established database will act as a baseline against which future change can be assessed.

KEY WORDS: Bonaire, reef fish, volunteer monitoring

## INTRODUCTION

Effective conservation and management of resources in a marine protected area require assessment for site characterization and monitoring to detect changes in the natural community. Unfortunately, the costs associated with *in situ* activities, coupled with the unreliable nature of marine conditions, make the consistent acquisition of sufficient data difficult. In addition, the available scientific manpower is often insufficient to generate the amount and diversity of information needed for research or monitoring (Pattengill-Semmens and Semmens 1998). As a result, resource managers have recently begun to utilize volunteer groups. The advantages of such programs include:

i) The costs of assessing the resource are often born by the volunteers, and the southeastern United States and Caribbean regions, where catches have declined dramatically over the past few decades (Bannerot et al. 1987, Bohnsack et al. 1994, Sadovy 1994). Conventional regulation of catch and effort has apparently done little to prevent overfishing of grouper stocks (Chiappone et al. 2000). Nassau grouper (*Epinephelus striatus*) and jewfish (*E. itajara*) are considered commercially extinct throughout much of the Caribbean (Sadovy 1994) and are protected in the southern Atlantic waters of the United States (including Puerto Rico and the U.S. Virgin Islands). With the authorization of the Sustainable Fisheries Act in 1996, the emphasis of fisheries management has shifted to include conservation of essential fish habitat and the creation of non-extractive marine reserves (Rosenberg et al. 2000). Recently, a number of studies have investigated the habitat preferences of groupers (Eggleston 1995, Sluka et al. 1996a,b, Sullivan and Sluka 1996, Sluka et al. 1998) and the efficacy of marine reserves in protecting grouper stocks (Sluka et al. 1997, 1998, Chiappone et al. 2000). To date, species-specific patterns of habitat preference remain unclear. Most species appear to prefer moderate to high-relief habitats with abundant holes and crevices, while some prefer isolated patch reefs with surrounding sandy bottom (reviewed in Sluka et al. 1996a). Among-habitat distribution of grouper depends primarily on a combination of habitat preference and fishing pressure, in addition to other biotic and abiotic factors (Sluka 1995). Within a preferred habitat, distribution will also depend on resource allocation such as food, shelter, and cleaning stations (Sluka 1995). However, patterns of fishing pressure are likely more important than habitat in determining grouper distribution (Sluka et al. 1996a), and studies of habitat preference may therefore be confounded by the effects of exploitation.

Healthy populations of grouper still exist in the Turks and Caicos Islands (TCI), where they support small-scale subsistence fisheries. The Turks and Caicos Islands, located at the southeastern end of the Bahamian Archipelago, support a relatively sparse human population, and a large portion of the archipelago remains uninhabited. Fishing pressure is therefore localized around three population centers: Providenciales, Grand Turk, and South Caicos. Many areas within this archipelago remain virtually unfished. The primary method of harvesting is spearfishing (using a Hawaiian sling) from small (< 5 m) outboard skiffs. Two lobster boats operating out of South Caicos also land grouper as bycatch from their traps. Current management for grouper and other finfish species involves only three regulations:

i) A restriction on the use of trigger-operated spear guns,
ii) A ban on the use of SCUBA for any harvesting, and
iii) A series of small marine reserves in which all extractive activities are disallowed.

The ban on SCUBA effectively restricts the harvest of grouper to depths shallower than ~ 20 meters. Lobster traps are typically set within this depth range also (W. Clerveaux, Turks and Caicos Dept. of Environment and Coastal Resources, personal communication). Populations of grouper in the Turks and Caicos Islands represent an ideal opportunity to study habitat preferences of grouper without the confounding effects of exploitation and to determine the efficacy of small marine reserves in protecting groupers from localized exploitation. The objectives of this study were:

i) To determine the density of juvenile, intermediate and adult life history stages of groupers in a variety of habitats on the Caicos Bank, Turks and Caicos Islands, and
ii) To compare the density of groupers inside and outside of the Admiral Cockburn Land and Sea Park, a small marine reserve located on the south shore of South Caicos.

## METHODS

**Study Sites**

The study area was located at the eastern end of the Caicos Bank, Turks and Caicos Islands (Figure 1). The Caicos Bank is a shallow, oolitic limestone platform that rises abruptly from depths of 2000 - 4000 m. The platform is bordered by extensive coral reefs. These shelf edge reefs typically occur at 15-20 m depth and drop almost vertically to a depth of several hundred meters.

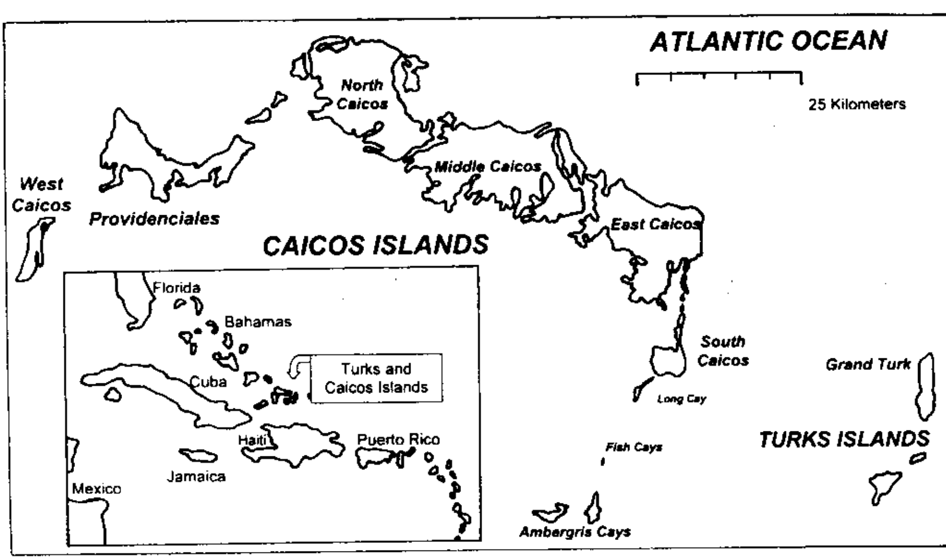



**Figure 1.** Map of the Turks and Caicos Islands, showing their location within the wider Caribbean region.

The Caicos Bank also supports extensive shallow sand flats, mangroves, seagrass beds, and shallow fringing and patch reefs. The study area was broadly divided into three zones:

i) The Admiral Cockburn Land and Sea Park (ACLSP, Figure 2) from the southeastern tip of South Caicos (High Point) to the southwestern tip of Long Cay (SWLC). This zone is closed to all fishing, although some poaching occurs (author's personal observations).

ii) The area north of the ACLSP from High Point to Plandon Cay. This zone is only lightly fished due to rough sea conditions and the prevalence of sharks.

iii) The area south of the ACLSP from SWLC to Ambergris Cay. Moderate fishing pressure is concentrated in this area, which is shallower and less turbulent than the windward zone north of the ACLSP. Within these three zones, 23 sites representing four habitat types were surveyed. The habitat types included fringing reef, channel reef, patch reef, and shelf-edge bank reef. All habitat types were represented in each of the three zones.

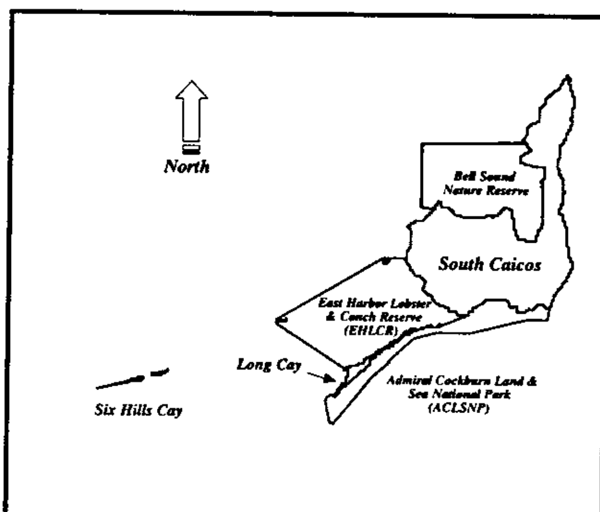



**Figure 2.** Location of the Admiral Cockburn Land and Sea Park, South Caicos, Turks and Caicos Islands.

**Census Technique**

In order to compare our results to those of previous studies in other regions, we replicated the survey methods used by Sluka et al. (1996a) and Chiappone et al. (2000). At each site, abundance and total length (to the nearest cm) of six grouper species were visually estimated along 10 - 20 haphazardly-placed transects measuring 20 m x 5 m. The species surveyed included Nassau grouper (*Epinephelus* *striatus*), yellowfin grouper (*Mycteroperca venenosa*), tiger grouper (*M. tigris*), red hind (*E. guttatus*), graysby (*E. cruentatus*) and coney (*E. fulvus*). Of these, only the Nassau and yellowfin groupers are commonly targeted by fishers, despite the fact that adult yellowfin grouper have been implicated in cases of ciguatera poisoning (Smith 1997). Groupers observed on the transects were classified according to three size categories. Larger groupers (Nassau, yellowfin and tiger) were categorized as follows: juveniles 0 - 15 cm total length (TL), intermediates 16 - 40 cm TL, and adults > 40 cm TL. Smaller species (red hind, graysby and coney) were categorized as: juveniles 0 - 10 cm TL, intermediates 11 - 20 cm TL, and adults > 20 cm TL.

**Statistical Analysis**

Data were tested for normality of distribution using the Wilke-Shapiro test and homogeneity of variance using Levene's test. For all species, density data were non-normal and variances were unequal. Monotonic transformations failed to normalize the data or homogenize the variance. Kruskal-Wallis non-parametric analysis of variance was therefore used to compare density of each life history stage among habitats and zones separately. Spearman rank correlations were used to determine the relationship between grouper density and depth.

## RESULTS

Non-parametric analysis of variance indicated that the population densities of most grouper species differed among habitats and/or zones during one or more life history stages, and that the patterns of density among habitats and locations differed throughout ontogeny for nearly all species. A weak positive correlation existed between the depth of the transects and the density of intermediate and adult coney ($R = 0.21$, $P < 0.05$ and $0.28$, $p < 0.001$, respectively) and adult Nassau grouper ($R = 0.24$, $p < 0.01$). The density of remaining grouper species and life stages showed no relation to depth ($R < 0.2$, $p > 0.05$). The results for each species are presented separately below.

**Coney (*Epinephelus fulvus*)**

For all life history stages, mean density of coney differed significantly between habitats (Kruskal-Wallis test, $H = 12.52$, $p < 0.01$). Densities of juveniles and intermediates were highest on shelf edge bank reefs and lowest on patch reefs (Figure 3a). Density of adults was also highest on the shelf edge, but did not appear to differ between fringing reefs and patch reefs (Figure 2). Mean density of juvenile coney did not differ among the three zones ($H = 3.75$, $p > 0.1$). Density of intermediate and adult coney was higher in the ACLSP than in either of the fished zones (Figure 3b). None of the life history stages differed in density between the northern and southern zones (Kruskal-Wallis test, $p>0.05$ for all cases).

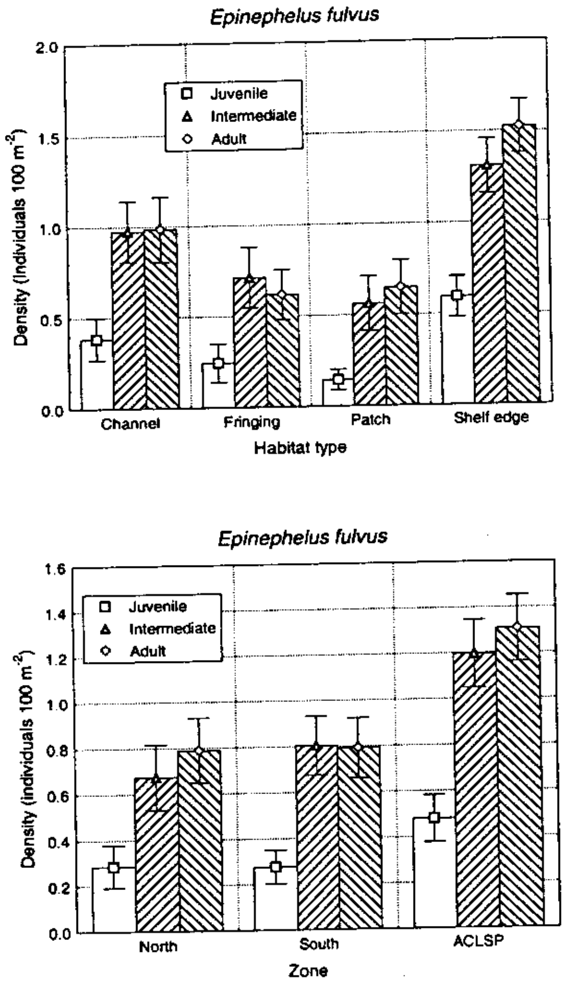
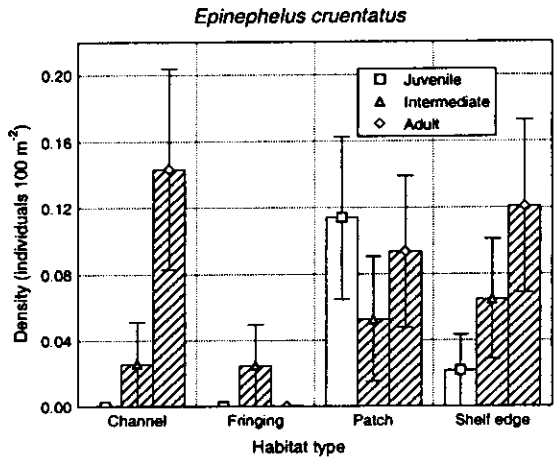



**Figure 3.** Mean density of coney among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

**Graysby (*Epinephelus cruentatus*)**

Juvenile graysby were found only on the shelf edge bank reefs (Figure 4a). Intermediate graysby were found in all habitat types. Adults were absent from fringing reefs. There were no significant differences among habitat types in mean density of intermediate or adult graysby (Kruskal-Wallis test, $p > 0.1$). Mean density of graysby did not differ significantly among zones in any life history stage ($p > 0.1$ for all cases), although there was a tendency for juvenile and adult density to be higher in the southern zone of greatest fishing pressure (Figure 4b).



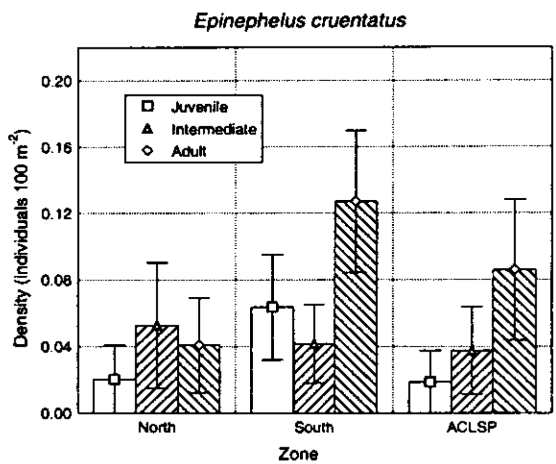
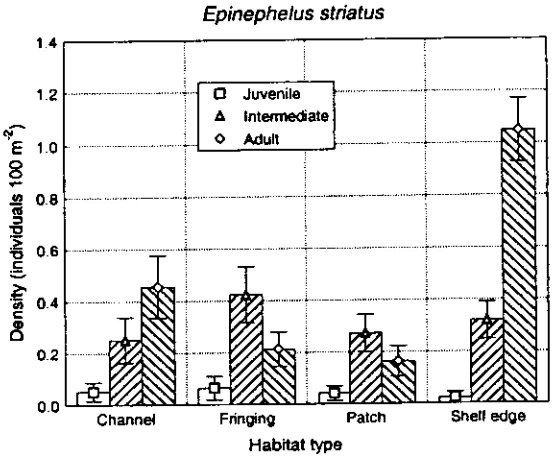




**Figure 4. Mean density of graysby among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.**

**Nassau grouper (*Epinephelus striatus*)**

There were no significant among-habitat differences in mean density of juvenile or intermediate Nassau grouper (Kruskal-Wallis test, $H = 0.66$, $P > 0.01$ and $H = 1.78$, $P > 0.01$, respectively). Mean density of adult Nassau grouper was significantly higher on shelf edge bank reefs ($H = 36.73$, $P < 0.001$, Figure 5a). Similarly, juvenile and intermediate density did not differ between zones, whereas adult density was significantly higher in the lightly fished northern zone than the southern zone or the ACLSP ($H = 11.96$, $p < 0.001$, Figure 5b).



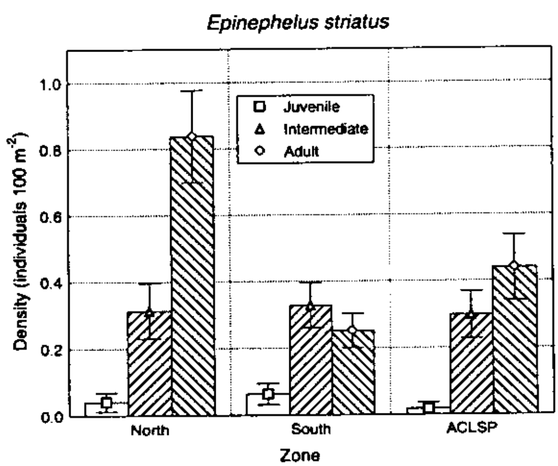




**Figure 5.** Mean density of Nassau grouper among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

**Red hind (*Epinephelus guttatus*)**

No juvenile red hind were observed over the course of this study. Mean density of intermediate and adult red hind did not differ significantly among habitats, although there was a tendency toward higher adult density on patch reefs (Kruskal-Wallis test, $p > 0.1$ for all cases, Figure 6a). Density of intermediate red hind did not differ between zones. Adult red hind, however, were significantly less common in the northern zone than in the southern zone or the ACLSP ($H = 6.32$, $p < 0.05$, Figure 6b).

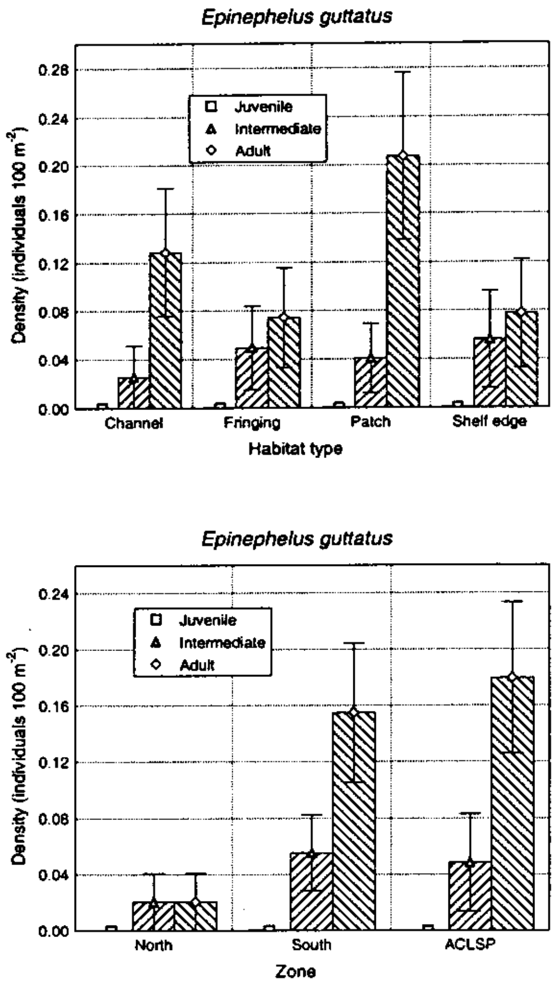



**Figure 6.** Mean density of red hind among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

**Tiger grouper (*Mycteroperca tigris*)**

Mean density of juvenile tiger grouper differed significantly among habitats (Kruskal-Wallis test, $H = 3.54$, $p > 0.1$). Juvenile density was highest in channel habitats (Figure 7a). Juveniles were not observed on fringing or shelf edge reefs. Mean density of intermediate tiger grouper did not vary significantly among habitats. Adult density was significantly higher in channel habitats but did not differ between fringing, patch or shelf edge reefs ($H = 9.92$, $p < 0.05$, Figure 7a). Juvenile tiger grouper did not occur in the northern zone but did not differ significantly in density between the southern zone and the ACLSP. Intermediate tiger grouper were not found in the southern zone, but no significant difference in mean density of intermediates was detected among zones ($H = 4.14$, $p > 0.1$, Figure 7b). Mean density of adult tiger grouper was significantly higher in the ACLSP than in either of the fished zones ($H = 14.80$, $p < 0.001$).

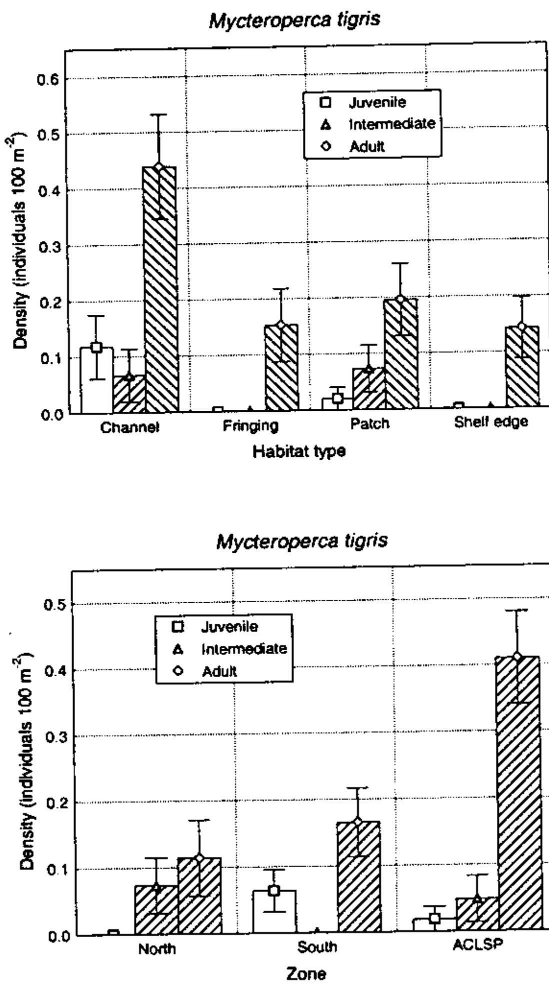
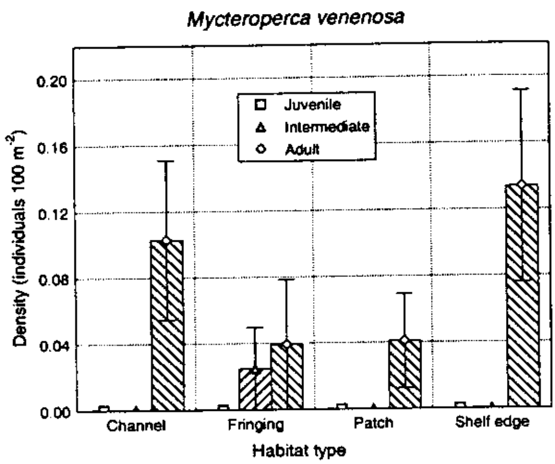



**Figure 7.** Mean density of tiger grouper among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

**Yellowfin grouper (*Mycteroperca venenosa*)**

No juvenile yellowfin grouper were observed in this study. Intermediate stage yellowfin grouper were found only on fringing reefs in the northern zone (Figures 8a,b). Mean density of adult yellowfin grouper did not differ significantly among habitats (Kruskal-Wallis test, $H = 3.67$, $p > 0.1$), although there was a tendency for density to be higher on shelf edge reefs than on fringing or patch reefs. Mean adult density differed significantly among zones ($H = 7.85$, $P < 0.05$) and was highest in the ACLSP but did not differ between fished zones (Figure 8b).



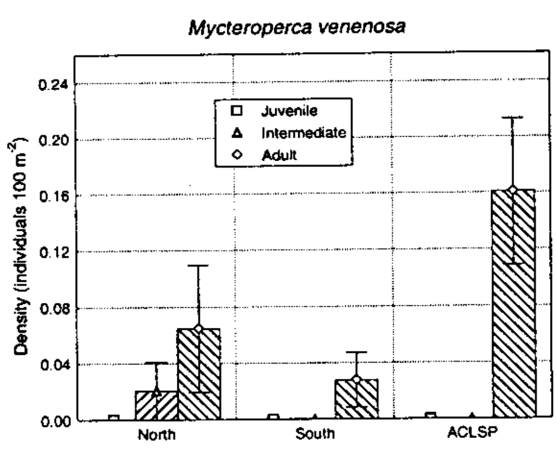




**Figure 8.** Mean density of yellowfin grouper among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

## DISCUSSION

**Habitat Preferences of Grouper**

Determining essential fish habitat (EFH) for all life stages is imperative to effective conservation of exploited or otherwise threatened stocks (Benaka 1999). However, this task becomes more difficult when the species in question do not appear to prefer a particular habitat type. Areas not inhabited by a species obviously do not constitute EFH, but other areas inhabited by that species may not be essential in maintaining that species' productivity (Minello 1999). Sluka et al. (1996a) suggested that in the absence of obvious habitat preference by Nassau grouper, all areas inhabited by this species must be considered "essential" and protected accordingly. Several studies have investigated habitat preferences of groupers in the wider Caribbean region (Nagelkerken 1981, Alevizon et al. 1985, Sluka and Sullivan 1996, Sluka et al. 1996a,b). Groupers are typically most abundant in moderate to high relief habitats with abundant crevices, ledges or caves (Nagelkerken 1981, Coleman et al. 1996, Sluka et al. 1996b). Smaller species such as coney and red hind may prefer isolated patch reefs (Nagelkerken 1981) and may be more abundant in low-relief habitats (Sluka et al. 1996b). Other studies have shown a preference for deeper waters by larger size classes (Thompson and Munro 1978, Coleman et al. 1996).

In this study, adult Nassau grouper and all life stages of coney were most abundant on deep (15 - 20 m) shelf edge reefs. In contrast, Sluka et al. (1996a) found no differences in either coney or Nassau grouper density among habitat types (channel reefs, fringing reefs, and windward hard-bottom) in the Exuma Cays, Bahamas. This difference may be due in part to the differing geomorphology's of South Caicos and the Exuma Cays. The windward shelf off South Caicos is very narrow and drops from a depth of 15 - 20 m to depths of 300 m or more within 200 - 300 m from shore. The coral reefs occurring on this shelf edge are structurally highly complex, with a high proportion of live coral cover and extensive caves, ledges, and crevices. In comparison, the windward hard-bottom of the Exuma region drops rather less abruptly (author's personal observations) and has low complexity and relief (Sluka et al. 1996a). Sluka et al. (1998) found that Nassau grouper and black grouper (*Mycteroperca bonaci*) were most abundant in moderate to high relief habitats in the Florida Keys. In South Caicos, shelf edge reefs had the highest relief of any habitat. Nagelkerken (1981) reported that coney preferred isolated patch reefs surrounded by sandy bottom, but coney in South Caicos were less abundant on patch reefs than on channel or shelf edge reefs. Sluka et al. (1996a) suggested that coney in the Exuma Cays preferred low-relief habitat, although they found no significant differences in density among habitat types. Chapman and Kramer (1999) found no correlation between depth, substrate complexity or coral cover on the density of coney and graysby in Barbados. The remaining species surveyed at South Caicos showed little difference in density among habitat types.

In synthesis, the results of this and previous studies may indicate a lack of specific habitat preference by several grouper species. In other words, specific habitats may be or more less suitable depending upon other location-specific factors such as food availability, hydrography, interspecific competition, etc. The tendency of larger species (Nassau, yellowfin and tiger groupers) to be more abundant in shelf edge and channel habitats may reflect habitat selection or may be a function of fishing pressure. Shelf edge reefs are deep (15 - 40 m) and harvesting grouper from these habitats is difficult for most spear fishers using snorkel gear. Channel reefs are subject to tidal flows of several knots. This causes high turbidity and makes spear fishing difficult. Thus, the higher density of adult Nassau grouper on shelf edge reefs could result from the level of natural protection from fishing afforded by the depth of this habitat. This is supported to some extent by the weak but significant correlation between adult Nassau grouper density and depth. The problem with this explanation is that fishing pressure on groupers around South Caicos is low, and density of most grouper species is much higher at South Caicos than elsewhere in the northeastern Caribbean region (see Chiappone et al. 2000). Thus, it remains unclear whether the high density of Nassau grouper on South Caicos shelf edge reefs is a function of habitat selection or fishing pressure. In the case of coney, the higher shelf edge density may reflect habitat preference as this species is not subject to fishing pressure. It is obvious that managing fish stocks based on EFH is easier for those species that have clearly defined habitat preferences. However, Sluka et al. (1996a) point out that groupers use a wide range of habitat types throughout their life cycle. They suggest that in the case of grouper it is more important to protect reefs from fishing than to protect "optimal" grouper habitat from fishing.

**The ACLSP as a Fishery Reserve**

Mean density of coney, adult tiger grouper and adult yellowfin grouper was significantly higher within the ACLSP than outside the park. Whether or not these patterns of distribution are actually caused by fishing pressure is unclear. In Barbados, where coney are targeted by the trap fishery, their mean density was significantly higher within the Barbados Marine Reserve (BMR) than on fished reefs in 1995 (Tupper and Juanes 1999), but not in 1992 (Rakitin and Kramer 1996) or 1996 (Chapman and Kramer 1999). Coney and tiger grouper are not targeted by South Caicos fishermen, so it seems unlikely that fishing pressure would determine their distribution. The higher mean density of tiger grouper in the ACLSP probably resulted from a single channel reef site at which the density of this species was particularly high.

Of the larger, commercially exploited groupers, density of adult yellowfin grouper was higher within the ACLSP while density of adult Nassau grouper was higher north of the park. This result is opposite of what was expected, since fishing pressure on Nassau grouper is much higher than on yellowfin grouper. There are several possible reasons for this pattern of species density. First, it is possible that yellowfin grouper are more susceptible to fishing pressure than Nassau grouper. Yellowfin grouper generally are less abundant than Nassau grouper (Sluka et al. 1996a,b, Chiappone et al. 2000, this study) and selective removal by spear fishers may deplete yellowfin grouper populations at a faster rate. This assumes that marine reserves would have a greater protective effect on species that suffer heavier fishing mortality – an idea supported by several published studies (Russ 1985, Russ and Alcala 1989, 1996). Alternatively, the lack of a measurable protective effect on Nassau grouper may stem from its long-distance spawning migration (Bolden 2000). Species that migrate to spawn will inevitably spend some period of time outside of the reserve boundaries. The longer the time spent outside the reserve, the more vulnerable fish become to fishing mortality (Chapman and Kramer 1999). The nearest Nassau grouper spawning aggregation is roughly 40 km from the ACLSP. In contrast, tiger and yellowfin grouper are known to aggregate just 200 - 300 m outside the eastern boundary of the park, at the southeastern tip of South Caicos (see Figure 2). Despite its location outside the park boundaries, this aggregation site is rarely fished due to its depth (25 - 40 m), rough seas, and the frequency of shark encounters (T. Morris, personal communication and author's personal observations). Thus, if Nassau grouper spend longer periods outside the reserve boundaries, they will receive less benefit from the reserve than more sedentary species. Further research into the movements and home range size of larger grouper species is needed. It is very possible that the area covered by the ACLSP (8 $km^2$) is smaller than the home range of adult Nassau grouper. Nassau grouper density was higher in the Exuma Cays Land and Sea Park (ECLSP) than in surrounding fished areas (Sluka et al. 1996a), but the area covered by the ECLSP is 442 $km^2$.

Finally, the observed patterns of grouper density with respect to the ACLSP may reflect random variation and may have little to do with fishing pressure. This seems plausible given the low fishing pressures on South Caicos grouper and given that the density of most groupers in fished areas of South Caicos is two to four times greater than in protected areas elsewhere in the Caribbean. For example, Chiappone et al. (2000) reported a mean density of 0.35 individuals per 100 $m^2$ in the ECLSP and noted that this density was the highest recorded in the northeastern Caribbean. Mean density of Nassau grouper in the ACLSP was 0.67 individuals per 100 $m^2$. To the north of the ACLSP, mean density was 1.27 individuals per 100$m^2$.

## CONCLUSIONS

Despite recent efforts, it remains unclear whether grouper actively select preferred habitats, although it is apparent that they make use of a wide range of habitat types. The ACLSP may be too small to effectively protect commercially important species such as the Nassau grouper which undergo seasonal spawning migrations. Therefore, effective grouper management may require that marine reserves be used in conjunction with seasonal closures during spawning (see Beets and Friedlander 1999), and perhaps the protection of migration corridors between reserves and spawning aggregation sites.

Given the very high density of South Caicos groupers relative to other Caribbean islands, present levels of fishing pressure may not be intense enough to result in a density differential between fished and protected reefs. However, rapid tourism development on the western island of Providenciales has led to an increased demand for grouper and snapper, which are popular menu items with tourists. This in turn has led to a rapid decline in the number of groupers seen by recreational divers in Providenciales (M. Taylor, Coastal Resources Management Project, personal communication). Recently, developers began construction of a large resort complex on South Caicos. An influx of tourists to South Caicos may increase the demand for fresh snapper and grouper, resulting in heavier fishing pressure on local grouper stocks. If so, the enforcement of the ACLSP, in conjunction with other management measures as mentioned above, may be an important step in ensuring the sustainability of grouper in South Caicos.

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