# Benthic Habitat Characterization and Space Utilization by Juvenile Epinepheline Groupers in the Exuma Cays Land and Sea Park, Central Bahamas

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ABSTRACT

Previous studies of grouper habitat have been mainly descriptive, emphasizing general community characteristics. A study was initiated in the central Bahamas to quantify key benthic habitat parameters in relation to individual groupers with previously estimated home ranges. A 10 x 13 $m^2$ grid was positioned over the home range of two coneys (*Epinephelus fulvus*) and a juvenile Nassau grouper (*E. striatus*). Parameters utilized to characterize features of the benthic community included: 1) percent coverage of conspicuous benthic invertebrates and algae, and 2) density and area coverage of sponges and stony corals. The positions of groupers within the grid were recorded every 30 seconds for random twenty-minute intervals over a period of twelve days. The presence or absence of a grouper cleaning station was found to have the most significant effect on space utilization. Other habitat variables, including sponge density, coral colony density, and coral area coverage, were found to be of secondary importance. This study attempts to quantify important habitat parameters for groupers. The results may have implications for the design of marine fisheries reserves in the tropical western Atlantic.

KEY WORDS: *Epinephelus*, grouper, cleaning station, habitat, marine fishery reserves, Bahamas.

## INTRODUCTION

Current information on the habitat of epinepheline groupers is sparse and mainly qualitative, particularly for juvenile phases. There is little information on the factors influencing the movement and space utilization of grouper species; most studies have focused on gross benthic features as related to grouper abundance. Previous benthic surveys of grouper habitats have classified areas according to coarse-level features, including vertical relief, bottom type (*e.g.*, hard bottom), and community designation (*e.g.*, patch reef). There exists a need to quantify benthic habitat parameters that are important influences on the spatial utilization of grouper species. This information can aid in determining areas appropriate for fisheries reserves or habitat enhancement/restoration projects.

In general, groupers are more abundant on extensive continental shelf areas rather than narrow shelf areas (Bannerot *et al.*, 1987), and tend to be secretive fish, occupying caves, crevices, and ledges (Smith, 1961). Juvenile grouper tend to occupy nearshore habitats compared to adults (Stewart, 1989). Nassau groupers (*E. striatus*) occur on high-relief coral reef communities and over rocky bottoms (Bannerot *et al.*, 1987; Stewart, 1989). Adult red groupers (*E. morio*) are mainly found over rocky bottoms with crevices, ledges, and caverns (Moe, 1969), while juveniles occur over hard bottoms (Jory and Iverson, 1989). Juvenile and sub-adult red groupers under 50 cm in length tend to inhabit nearshore reef areas (Beaumariage and Bullock, 1976). Nagelkerken (1981) found coneys (*E. fulvus*) and red hinds (*E. guttatus*) to be most abundant in Curaçao on isolated patch reefs surrounded by sandy bottoms. Graysbys (*E. cruentatus*) were most abundant on coral reefs with high vertical relief and numerous holes, crevices, and caves for shelter (Nagelkerken, 1979, 1981). The abundance of graysbys in Curaçao was related to the quantity of stony coral cover, particularly the abundance of *Montastrea annularis* and *Agaricia* spp. (Nagelkerken, 1979, 1981).

Groupers are commercially important throughout the Caribbean (Thompson and Munro, 1978). Conventional approaches of fisheries management plans have focused on fisheries landings. Commercial landings for the Florida Keys and southwest Florida increased from 1,676,024 pounds in 1979 to 3,576,525 pounds in 1986 (Brown *et al.*, 1991). Since 1986, there has been a decrease in landings in south Florida, and by 1990 only 1,572,730 pounds were caught. The traditional methods of protecting grouper stocks have not resulted in an increase in grouper populations. The Plan Development Team (1990) proposes marine fisheries reserves as the best solution to preserving the integrity of fish stocks. However, the lack of quantitative information on benthic community parameters important to juvenile groupers is a hindrance to the development of such reserves. The marine fishery reserve approach attempts to quantify habitats that are critical for fishery target species. Information is needed on specific habitat requirements for groupers to aid in setting aside areas for inclusion in fisheries reserves.

Concurrent with declines in fisheries landings is the degradation of nearshore marine benthic communities throughout south Florida and the Caribbean. Of particular interest to groupers are nearshore hard bottom communities including octocoral-sponge communities and patch reef communities. Causes of community degradation are many and synergistic in impact; these include, but are not restricted to, sewage pollution, changes in circulation or runoff by coastal development, sedimentation, and mechanical damage. We propose that habitat management may be a viable alternative to traditional stock assessment measures; the condition of nearshore marine benthic communities will likely influence fisheries populations, both in terms of habitat suitability and recruitment, regardless of fishing pressure.

The activity patterns of juvenile groupers in the central Bahamas were studied in relation to quantified benthic community parameters, including coverage of gross lifeform features and more detailed information on benthic invertebrate abundance. The purpose of this investigation is to present results of the space utilization of groupers in relation to specific benthic community features and the spatial patterning of benthos. Quantitative models are developed to describe benthic community parameters that significantly affect the movement and space utilization of three individual groupers.

## MATERIALS AND METHODS

### Survey Site and Benthic Characterization

The study site is part of a long-term monitoring effort and was used to investigate the activity and movement of groupers in relation to habitat characteristics. The grouper observation site consisted of a low-relief limestone pavement in a tidal channel offshore of Waderick Wells Cay (see Sullivan and Chiappone, 1992). The observation site was a shallow (3-4 m), complex matrix of substratum features, including isolated coral heads, barren sand-mud, and large encrusting sponges. Hard-bottom communities occurring in tidal channels are unique community types in the Bahamas; strong semi-diurnal tides generate currents which flow onto and off of the Bahama Banks via cuts and channels between islands (Sullivan and Chiappone, 1992).

Benthic community characterization methods are outlined in Sullivan and Chiappone (1992). Substrata and lifeform coverage information was first measured for gross benthic features. The survey area was selected to include the known home ranges of both conies and Nassau groupers. Within the 10 x 13 m2 survey area, 1-m2 quadrats were surveyed. For each 1 m2 sampled, substrata and lifeform features were visually scored for percentage cover in each quadrat. Substratum categories included: (SM) sand-mud, (S) coarse oolitic sand, (RB) rubble, and (HR) hard reef. Lifeform categories included: (SG) seagrass, (AT) algae, (SP) sponges, (SC) octocorals, and (HC) stony corals. Each category for substratum and lifeform was scored independently for each sampled quadrat (1 m2) for a coverage class designation: (0) not present, (1) < 10 %, (2) 10-30 %, (3) 30-70 %, and (4) > 70 % coverage. The midpoints of the coverage classes were converted to square centimeters of coverage for analysis.

Density and area coverage of sponges, octocorals, and stony corals were measured in 12 grids (varying between 9 and 16 m2). Information was collected on the number of sponges, stony corals, and octocoral colonies. An individual sponge or coral colony was considered to be any individual growing independently of its neighbors. In cases where an individual or colony was clearly separated by the death of intervening portions, each living part was considered to be a separate individual. Relative dimensions of coral colonies (e.g., length, width, radii) were used to estimate the coverage (cm2) of each colony (Sullivan and Chiappone, 1992).

**Fish Surveys**

Sullivan and de Garine (1994) demonstrated that groupers, found in the Exuma Cays Land and Sea Park, a marine fishery reserve, occupied home ranges which appeared to be centered around a particular group of coral heads. Three fish were identified as study animals within the survey area: two coneys (*E. fulvus*) 242 mm and 300 mm TL, and one juvenile Nassau grouper (*E. striatus*) 381 mm TL. The larger coney was xanthic, which allowed for the distinction between the two individuals. Twelve 20-minute intervals were randomly chosen throughout the day for eight days. One observer watched the groupers while they were inside the 10 m x 13 m grid, and recorded the position of each grouper at 30-second intervals. Water clarity generally exceeded 20 m so the observer was able to remain a reasonable distance away from the subject so as not to influence its behavior. A record of the amount of time as a fraction of a twenty- minute interval that the grouper spent in a particular 1 m2 quadrat was constructed.

**Data Analysis**

Step-wise regression analysis was used for each fish to analyze the relationship among particular benthic community parameters and the mean amount of time spent in a grid per 20-minute interval (Draper and Smith, 1981). Parameters were added and deleted from the models at a probability level of 0.15. Lifeform and grouper space utilization data were pooled into 12 sub- grids to match the data on sponge and coral abundance. Models were built for each grouper individually using the benthic survey data. Variables tested in the step-wise regression procedure included visually scored lifeform attributes (coverage of algae, seagrass, sponges, octocorals, and stony corals) as well as actual measurements of sponge and colony density and coral coverage.

The eight habitat variables were selected for analysis based on information found in the literature that suggested possible relationships between benthic characteristics and space utilization of groupers. Each variable analyzed can be considered a measure of habitat complexity and as a possible indicator of habitat suitability for groupers. Information on grouper habitat utilization suggests that habitat complexity and vertical relief (e.g., caves, crevices and shelter) are the most important factors determining grouper distribution. Areal measures of coral coverage indicate the amount of structure and forage base that might be available for groupers. Density and area coverage of corals and sponges is related to spatial complexity (Sullivan and Chiappone, 1992). Habitats with low density and coverage of benthic organisms may indicate low spatial complexity. The complexity of a habitat, with combinations of low coverage and high density or vice versa, will depend on dominant taxa. The most spatially complex habitats have high density and coverage of benthic organisms. Algae provide possible prey refuge, apparently important for determining grouper distribution (Parrish, 1987), as well as indicating areas of dead coral or rubble.

The presence of a cleaning station was mapped in the 10 x 13 m2 grid. The presence or absence of cleaning stations was represented by a 'dummy' variable in the regression model: 0 = absence of cleaning station, 1 = presence of a cleaning station. Sub-grid 6 contained cleaning stations inhabited by cleaner fishes of the genus *Gobiosoma*. Sub-grid 9 contained a number of cleaner shrimp of the genus *Periclimenes*. The fish cleaning stations were associated with high- relief structures, while the shrimp cleaning station was located a few meters away in a low relief sandy area.

Substratum categories, including sand-mud, sand, rubble, and hard reef, were not found to be useful in correlating grouper space utilization to specific benthic features. The scattered coral heads on the northern end of the grid had a significant accumulation of sand immediately downstream. Subsequent statistical analyses indicated that certain substratum features (e.g., sand) that were superficially related to the presence of the coral heads were significantly related to grouper space utilization. Substratum categories were considered sampling artifacts and not included in the statistical models.

Homogeneity of variances between regression variables was first tested using Bartlett's test (Zar, 1984). Variances were initially found to be heteroscedastic ($X2 = 902.6$, $p < 0.001$). Data values for lifeform cover and time spent by fish were subsequently transformed using a natural logarithmic (loge) transformation. Due to the high number of zero values for octocoral area coverage, this variable was dropped from the transformation and subsequent analyses. After transformation, variances were found to be homoscedastic ($X2 = 11.2$, $p > 0.05$).

## RESULTS

### Habitat Variables

The study was characterized as a low-relief limestone pavement with scattered rubble and coral heads. The south side of the site was a flat, lower relief area with large encrusting sponges (*Anthosigmaella varians*). The western side of the site was a sandy shoal area. The eastern edge had an accumulation of sand-mud along the sides of the tidal channel, with a sparse coverage of calcareous green algae (*Penicillus* spp., *Halimeda* spp.) and small colonies of stony corals (*Porites astreoides, Manicina areolata*). The northern end of the site had scattered remains of coral heads (*Montastraea annularis, Siderastrea* *siderea)* and increased rubble. The site was characterized as a hard-bottom covered with a thin layer of sand-mud or sand. Rubble covered a small proportion of the sampling units, but was seen throughout the site. There was no seagrass and a low frequency of octocoral colonies. The area was visually dominated by algae and sponges, but stony corals were found throughout the site.

A summary of benthic habitat characteristics from the survey area is presented in Table 1. Benthic habitat attributes measured included: algal coverage, sponge coverage, coral coverage, sponge density, coral colony density, and colony sizes. Cleaning stations were observed in 2 of the sampled grids. Coverage by algae ranged from 5 to 25 % in sampled quadrats; the greatest cover occurred in the grid with one of grouper cleaning stations (Table 1). Sponge coverage ranged from 0.5 to 46 %, and was highest on the southern side of the site where large mat sponges were observed. Sponge coverage was low (< 9 %) in both grids containing the cleaning stations. Hard coral coverage was consistently low over the entire survey area (< 2 %). Sponge density varied from 0.58 to 11.00 individuals per m2. Coral colony density ranged from 0.58 to 3.17 colonies per m2; *Porites astreoides* was numerically the abundant coral. Colony sizes were small, ranging from less than 1 to 1080 cm2 in size. The largest coral colonies were specimens of *Montastraea annularis* (1080 cm2) and *Siderastrea siderea* (780 cm2); one of the two cleaning stations occurred in the same grid (6) as the largest coral colony (Table 1). Only one octocoral colony, a specimen of *Eunicea mammosa*, was observed over the entire survey area.

**Grouper Observation Summary**

Table 2 presents information on the space utilization of groupers at the study area. All three fish spent the most amount of time in the grids containing the cleaning stations. The Nassau grouper was observed for 979 minutes, the xanthic coney for 1225.5 minutes, and the bicolor coney for 993.5 minutes over the 8-day duration of the study. A correlation matrix and associated probability levels were used to assess the relationship among the measured benthic features and the amount of time a grouper spent in a particular quadrat (Table 3). Variables that entered the stepwise regression model for all three fish ($p < 0.15$) were algal coverage, numbers of sponge individuals, stony coral coverage, and the presence or absence of cleaning stations. For the Nassau grouper and the xanthic coney, the area coverage and mean size of stony coral colonies also entered the regression model. These variables were analyzed with a step-wise regression procedure. The variable which explained the most variance in the data was the presence or absence of a cleaning station. Once this variable was entered into the model, the significance level decreased for the other variables in the model ($p > 0.15$). The regressions of presence or absence of cleaning stations on the mean time spent in a particular grid per 20-minute observation period

**Table 1.** Benthic lifeform coverage summary for algae, sponges, and stony corals at the grouper study site, Exuma Cays, Bahamas. Coverage ($cm^2$ $m^-2$) of algae (AT), sponge (SP), and stony corals (HC) was visually scored for percentage cover in 1 $m^2$ quadrats. Mean sponge density, coral colony density, coral coverage ($cm^2$), and coral area per colony were subsequently measured in sub-grids (see text). Grids 6* and 9* contained grouper cleaning stations.

| Grid | AT | SP | HC | No. Sponges $m^{-2}$ | No. coral colonies $m^{-2}$ | Coral coverage ($cm^2$ $m^{-2}$) | Coral area per colony ($cm^2$) |
|---|---|---|---|---|---|---|---|
| 1 | 875 | 50 | 375 | 1.67 | 1.00 | 32.3 | 32.3 |
| 2 | 500 | 210 | 330 | 0.58 | 0.83 | 39.1 | 47.0 |
| 3 | 625 | 330 | 330 | 1.50 | 0.58 | 10.1 | 17.3 |
| 4 | 781 | 500 | 563 | 3.13 | 1.69 | 44.9 | 26.6 |
| 5 | 1167 | 444 | 611 | 1.56 | 1.11 | 137.9 | 124.1 |
| 6* | 2500 | 822 | 667 | 10.0 | 2.33 | 186.2 | 79.8 |
| 7 | 1167 | 1000 | 444 | 4.56 | 2.11 | 51.8 | 24.5 |
| 8 | 1375 | 1000 | 500 | 3.58 | 3.17 | 70.0 | 22.1 |
| 9* | 1167 | 500 | 500 | 2.78 | 1.22 | 49.3 | 40.3 |
| 10 | 1330 | 1107 | 500 | 11.0 | 2.67 | 72.7 | 27.3 |
| 11 | 833 | 4611 | 500 | 3.00 | 3.00 | 72.5 | 24.2 |
| 12 | 2500 | 1375 | 417 | 2.67 | 1.50 | 15.9 | 10.6 |

**Table 2.** Grouper space utilization summary at the study site, Exuma Cays, Bahamas. The mean time spent in a particular grid per 20-minute observation period is reported for the three study groupers. Grids 6* and 9* contained grouper cleaning stations.

| Grid | Nassau Grouper | Gold Coney | Bi-color Coney |
|---|---|---|---|
| 1 | 0.067 | 0.044 | 0.750 |
| 2 | 0.038 | 1.298 | 0.625 |
| 3 | 0.010 | 0.035 | 1.125 |
| 4 | 0.029 | 0.017 | 0.427 |
| 5 | 0.048 | 0.509 | 0.729 |
| 6* | 12.967 | 10.623 | 6.495 |
| 7 | 0.202 | 0.825 | 0.740 |
| 8 | 0.000 | 0.114 | 1.469 |
| 9* | 2.894 | 2.948 | 1.068 |
| 10 | 0.038 | 1.430 | 0.421 |
| 11 | 0.019 | 0.175 | 0.250 |
| 12 | 0.087 | 0.272 | 0.542 |

were significant ($p < 0.01$) (Table 4). The constant of regression was not significant, indicating a regression line passing through the origin.

## DISCUSSION

The relative abundance of a particular species is largely determined by the available habitat (Orth, 1983). The particular resources of importance within a habitat would include refuge from predation, a food source, and the availability of cleaning organisms. The abundance and availability of resources are related to the benthic community present and the structure it provides. Groupers tend to be 'energy minimizers' (Sullivan and de Garine, 1994) by maximizing use of available resources while minimizing the energy expended to obtain them. Groupers are expected to spend significant amounts of time in areas where necessary resources (e.g., forage base, refuges) are readily available. The availability of these resources can be assessed by quantifying the underlying benthic community.

The presence of cleaning organisms has previously been shown to affect the space utilization of fishes (Slobodkin and Fishelson, 1974). Slobodkin and Fishelson (1974) compared the fish aggregations at cleaning stations to aggregations of animals at water holes or animal kills in East Africa. These cleaning stations could be very important in determining the distribution and diversity of fishes in certain areas. Groupers are frequent visitors to these cleaning stations (Mahnken, 1972; Johnson and Ruben, 1988). Several fish and shrimp are known to remove external parasites from fish (Johnson and Ruben, 1988). Slobodkin and Fishelson (1974) did not find any obvious morphological

Table 3. Correlation matrix (A) and associated probability levels (B) for model variables of space utilization for the Nassau grouper, xanthic coney and bi-color coney. Benthic lifeform atrributes visually scored for percent coverage are as follows: (AT) algae, (SP) sponges, and (HC) stony corals. Attributes measured in quadrats include: (SP_IN) density of sponges, (COR_COL) density of coral colonies, (COL_AREA) coral area per colony, (COR_AREA) coral area coverage, and (CLEAN) presence of absence of a cleaning station. ** = $p < 0.05$, ns = not significant.

A.

| | Nassau | Xanthic | Bi-color |
|---|---|---|---|
| Nassau | 1.000 | | |
| Xanthic | 0.987 | 1.000 | |
| Bi-color | 0.969 | 0.944 | 1.000 |
| AT | 0.536 | 0.518 | 0.524 |
| SP | 0.009 | -0.012 | -0.037 |
| HC | 0.515 | 0.498 | 0.459 |
| SP_IN | 0.485 | 0.493 | 0.452 |
| COR_COL | 0.172 | 0.182 | 0.163 |
| COR_AREA | 0.509 | 0.544 | 0.475 |
| CLEAN | 0.819 | 0.821 | 0.706 |

B.

| | Nassau | Xanthic | Bi-color |
|---|---|---|---|
| Nassau | ns | | |
| Xanthic | ns | ns | |
| Bi-color | ns | ns | ns |
| AT | ns | ns | ns |
| SP | ns | ns | ns |
| HC | ns | ns | ns |
| SP_IN | ns | ns | ns |
| COR_COL | ns | ns | ns |
| COL_AREA | ns | ns | ns |
| COR_AREA | ns | ns | ns |
| CLEAN | ** | ** | ** |

feature of the reefs of Eilat that would serve as congregation points for cleaner fish. However, Johnson and Ruben (1988) suggest that the availability of suitable substrata affects the distribution of cleaning fishes. The cleaner shrimp of the genus Periclimenes reach their highest abundance in sandy areas with low relief (Mahnken, 1972). It is possible that some benthic feature is related to the presence of the cleaning station and the behavior of the fish.

A significant relationship between quantified benthic community attributes indicates that these attributes influence the space utilization of groupers. The benthic feature most affecting grouper space utilization at the study site was the presence of a cleaning station. The effects of these cleaning stations on the space

**Table 4.** Regression and analysis of variance (ANOVA) tables for the Nassau grouper (A), xanthic coney (B), and bi-color coney (C).

**A.**

**Dependent variable: Nassau grouper N = 12 $R^2 = 0.671$**

| Variable | Coefficient | Std. Error | P (2 tail) | | |
|---|---|---|---|---|---|
| Constant | 0.054 | 0.712 | 0.941 | | |
| Cleaning Station | 7.877 | 1.745 | 0.001 | | |
| **Source** | **Sum of Squares** | **DF** | **Mean Square** | **F Value** | **Result** |
| Regression | 103.404 | 1 | 103.404 | 20.370 | $p < 0.001$ |
| Residuals | 50.76 | 10 | 5.08 | | |

**B.**

**Dependent variable: Xanthic coney N = 12 $R^2 = 0.675$**

| Variable | Coefficient | Std. Error | P (2 tail) | | |
|---|---|---|---|---|---|
| Constant | 0.472 | 0.566 | 0.424 | | |
| Cleaning Station | 6.315 | 1.386 | 0.001 | | |
| **Source** | **Sum of Squares** | **DF** | **Mean Square** | **F Value** | **Result** |
| Regression | 66.45 | 1 | 66.45 | 20.75 | $p < 0.001$ |
| Residuals | 32.02 | 10 | 3.20 | | |

**C.**

**Dependent variable: Bi-color coney N = 12 $R^2 = 0.498$**

| Variable | Coefficient | Std. Error | P (2 tail) | | |
|---|---|---|---|---|---|
| Constant | 0.708 | 0.399 | 0.106 | | |
| Cleaning Station | 3.074 | 0.976 | 0.010 | | |
| **Source** | **Sum of Squares** | **DF** | **Mean Square** | **F Value** | **Result** |
| Regression | 15.75 | 1 | 15.75 | 9.911 | $p < 0.01$ |
| Residuals | 15.89 | 10 | 1.59 | | |

utilization of groupers was significantly greater than all other benthic parameters. This was indicated by examining the partial correlation coefficients once the cleaning station variable was considered part of the regression model. The partial correlation coefficients for all other benthic community parameters were not significant once the cleaning station variable was entered into the regression model. While the effects of the cleaning stations at this site are the most important factors in determining grouper space utilization, the initial entrance of other benthic parameters into the regression model indicates that these parameters should be analyzed in future studies in order to assess their importance as grouper habitat and/or the presence of cleaning stations.

In a separate analysis by the primary author, the same three groupers were studied to determine their daily activity patterns. Groupers divide time between foraging, resting, or cleaning. Results from this study indicate that the Nassau grouper spent between 30 and 50% of its time cleaning; the xanthic coney 24 to 37%; and the bi-color coney 4 to 12%. Based on the relative amount of time spent at these cleaning stations, it appears that they serve an important role in the ecology of groupers. The cleaning stations appeared to serve several functions: (1) the removal of ectoparasites and (2) territorial markers and/or symbols of dominance. The Nassau grouper would frequently chase the coneys out of the cleaning station but would not remain to be cleaned. The Nassau grouper (381 mm) was also observed chasing a barracuda ( > 1 m) away from a cleaning station. The bi-color coney appeared to be on the low end of the dominance hierarchy of the three fish at this site; it was chased out of the cleaning station frequently by the other two groupers.

With specific quantitative models describing grouper habitat, developed over large areas, this information can be used to aid in the design of marine fishery reserves (MFRs). Important life history stages that would benefit from protection of habitat include: 1.) spawning aggregations, 2.) larval settlement, and 3.) juvenile stages. Groupers are known to gather in mass aggregations to spawn (Smith, 1972; Shapiro, 1987; Colin, 1992). These spawning aggregations are the target of many fisheries throughout the Caribbean (Olsen and LaPlace, 1979). Given the protogynous reproductive system of groupers, selective fishing of these aggregations could lead to a reduction in reproductive effort (Shapiro, 1987). This would reduce the number of possible new recruits. Information on the pre-settlement stages of groupers is sparse (Leis, 1987). The success of larval settlement is dependant upon quality habitat being available. Groupers spend several years as a juvenile and tend to occupy more nearshore habitats compared to adults (Stewart, 1989). These areas are most susceptible to habitat degradation and poor management. In order to protect these life history stages of groupers, habitat must be conserved.

MFRs are a viable management strategy proposed for the Southeastern United States to protect fish habitat (Plan Development Team, 1990), and have been shown to increase the abundance of fish (Alcala, 1988; Clark et al., 1989; Russ and Alcala, 1989), especially large predators such as serranids (Russ, 1985). Groupers could benefit from protection in MFRs, however in order to choose areas to protect, the best available habitat for given groupers must be known. Quantitative relationships between habitat parameters and grouper space utilization will provide explicit information to rank areas as to their 'quality' as habitat for different life history stages of groupers. These models will provide information on the niche requirements of groupers. When these requirements are delineated and combined with information on the species distribution, density, behavior, and foraging patterns of the groupers, powerful models can be built to predict the distribution and density of different species of grouper over large areas. This will provide an important tool for fisheries management of grouper habitat and the necessary information to design MFRs to protect this habitat. The conservation of grouper habitat will increase populations of grouper surrounding protected areas and result in economic benefit to fisheries based on these populations.

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