Mapping Ontogenetic Habitat Shifts of Coral Reef Fish at Mona Island, Puerto Rico

MICHELLE T. SCHÄRER, MICHAEL I. NEMETH, and RICHARD S. APPELDOORN
Department of Marine Sciences, University of Puerto Rico, Mayagüez, Puerto Rico 00681

ABSTRACT

Coral reef fishes use a variety of habitats throughout daily, ontogenetic, and spawning migrations, therefore requiring a suite of habitats to complete their life cycle. The use of multiple habitats by grunts (Haemulidae) and snappers (Lutjanidae) was investigated at Mona Island, a remote island off western Puerto Rico. The objective of this study was to determine if the distribution of three different life stages was random in relation to benthic habitat types. Coral reef fish were sampled throughout all habitat types randomly over a period of six months. For seven species of grunts and snappers median fork length was significantly different by habitat type identifying critical habitats for juveniles distinct from adult habitats. Within a life stage significant differences were observed in fish density by habitat type. Early juvenile grunts and snappers were more abundant in habitats of depths less than 5 m, mainly in rocky shores and seagrass areas with patches of coral or other hard structures. Larger juveniles were significantly more abundant in depths less than 5m in coral dominated habitats. Adults were abundant throughout the habitats of all depth ranges, except for two species *Haemulon chrysargyreum* and *Lutjanus mahogoni*, which were limited to shallower habitats. This suggests that coral reef fishes utilize specific habitats depending on life stage more so than species, therefore measuring species abundances without considering their life stage may provide misleading patterns of habitat use since ontogenetic migrations include a variety of habitats which are not necessarily the most abundant.

KEY WORDS: vReef fish, ontogenetic connectivity, habitat shifts

Cartografía de las Mudanzas de Habitáculos durante la Ontogenia de Peces de Arrecife en Isla de Mona, Puerto Rico

Los peces de arrecifes de coral utilizan una variedad de habitáculos durante migraciones diurnas, ontogenéticas y de reproducción, lo que requiere una complejidad de habitáculos para completar sus ciclos de vida. Se investigó la utilización de múltiples habitáculos por roncos (Haemulidae) y pargos (Lutjanidae) en la Isla de la Mona, una isla remota al oeste de Puerto Rico. El objetivo de este estudio es determinar si las distribuciones de tres estados de vida de estos peces eran aleatorias en relación a los habitáculos bénticos disponibles. Se muestrearon los peces de arrecifes de coral a través de todos los habitáculos durante seis meses. Para siete especies de roncos y pargos la mediana de tamaño (largo horquilla) fue significativamente diferente entre tipos de habitáculos, lo que sugiere que hay habitáculos críticos para juveniles distintos a los de los adultos. Dentro de un estado de vida se observaron diferencias significativas en la densidad de individuos por habitáculos. Los roncos y pargos de estados juveniles tempranos eran mas abundantes en habitáculos que se encontraban en aguas llanas (< 5 m de profundidad), principalmente en áreas rocosas y en hierbas marinas con parches de arrecifes. Juveniles de mayor tamaño se encontraron en abundancias mayores en habitáculos de corales de aguas llanas (< 5 m). Los adultos de todas las especies excepto 2 (*Haemulon chrysargyreum* y *Lutjanus mahogoni*) eran abundantes a través de todas las profundidades. Esto sugiere que los peces de arrecifes de coral utilizan habitáculos específicos dependiendo en gran medida de su estado de vida y menos en su especie, por lo tanto las mediciones de abundancia de peces debe considerar el estado de vida para mejor caracterizar sus patrones de utilización de habitáculos ya que las migraciones ontogenéticas incluyen una variedad de habitáculos que no son necesariamente los mas abundantes.

PALABRAS CLAVES:v Peces de arrecife, conectividad ontogenética, mudanzas de habitáculo

INTRODUCTION

In tropical marine ecosystems, diverse habitats support intricate networks which some species rely on and provide varying functions for populations to persist. The full extent to which species use habitats is still not well understood although it has been established that many species of coral reef fishes shift habitats as they grow (Appeldoorn *et al.* 1997, Lindeman *et al.* 2000, Nagelkerken *et al.* 2000, Dahlgren and Eggleston 2000, Cocheret de la Morinière *et al.*2002, Mumby *et al.* 2004, Dahlgren *et al.* 2006). Although general habitat preferences are known for some coral reef fish species, these change as they grow, therefore the ontogenetic connectivity of coral reef fishes across the sea-scape needs to be better understood in order to make recommendations in habitat protection prioritization. These linkages between habitats should be considered in the design of marine protected areas or marine reserve networks to be able to manage fisheries resources at the ecosystem's spatial scale.

The goal of this study is to determine how coral reef fish utilize habitat in relation to its overall abundance and distribution throughout the insular platform of Mona Island. Therefore, if fish were distributed at random throughout the available habitats we would expect to find no significant differences in the mean size or density of fishes by habitat type. Secondarily, we wanted to identify important habitats of three basic life stages (early juvenile, juvenile, and adult) of fish to explore linkages in their distributions that would indicate the ontogenetic connectivity between habitats. The benefit of observing this process at this particular offshore island is that it minimizes the effects of immigration and emigration from other shallow coral reef areas which are located at distances greater than 26 km. Based on these assumptions the patterns observed in this snapshot survey provide a simplified picture of ontogenetic connectivity of coral reef fishes at Mona Island.

METHODOLOGY

Mona Island is located in the center of the Mona Passage 73 km from the west coast of Puerto Rico (18˚ 5' 27" N and 67˚ 53' 37" W) (Figure 1). The main island, Mona, comprises 5,566 ha, and its satellite Monito is much smaller (14 Ha), located 6 km to the northwest and separated by a channel approximately 220 m in depth. The submerged insular shelf (< 100 fathoms depth) of Mona extends to 7,004 ha and at Monito it amounts to 2,575 ha where there is no beach or other shallow (< 25 m) habitats. Both islands are completely surrounded by deep waters of the Mona Passage up to 1,000 m. Benthic habitats less than 30m depth around Mona Island amount to approximately 2,174 ha and are composed of 92% coral reef and colonized hardbottom, 5% unconsolidated sediments and 3% submerged vegetation (NOAA 2001). The marine habitats of Mona Island include: Bedrock, limestone boulders and rubble areas on the north coast as well as fringing reefs, patch reefs, and spur and groove formations on the southern coasts. Limited areas of seagrass patches in back-reef lagoons are only present on the southern coast of Mona.

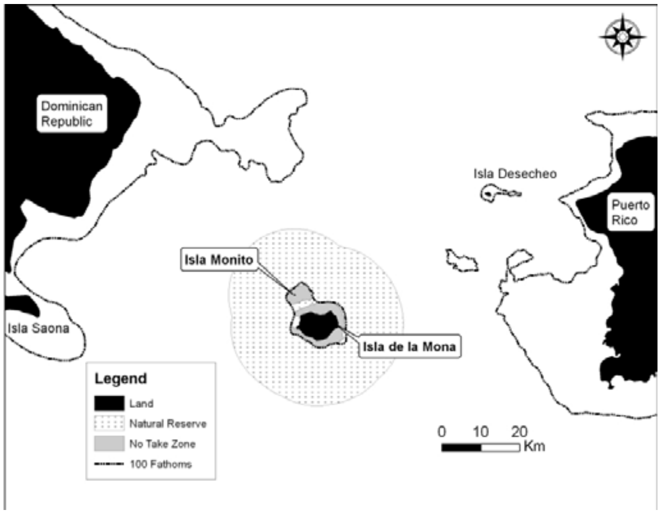

Figure 1. Location of Mona Island Natural Reserve, Puerto Rico.

Both islands are included in the Mona Island Natural Reserve, originally designated in 1919 as an Insular Forest although designation was extended to include the seas up to 9 nm (total area = 157,379 ha) around the perimeter of both islands in 1986 (Aguilar-Perera *et al.* 2006). Today it is managed by the Department of Natural and Environmental Resources of Puerto Rico (DNER), and although the islands are uninhabited, they are visited regularly by campers, hunters, fishers, and divers. A No-Take Zone extending to the 100 fathom contour (Figure 1) of Mona and Monito Islands has been designated in an amended fishery regulation (DNER Regulation 6902), however, the zone lacks education programs and enforcement therefore compliance is poor.

Data on coral reef fish distributions was collected uniformly for all fish species throughout the benthic habitat types of Mona Island. Monito Island was not surveyed due to depths greater than 25 m which limited time underwater. Each sampling site was chosen randomly from a 50 m grid superimposed upon a GIS layer of the insular platform of Mona Island. Sampling was limited to 25 m in depth due to SCUBA diving limitations. The coordinates for each sampling point were uploaded to a handheld GPS and located in the field. At each site (sampling point) a weighted buoy was dropped from the surface which marked the starting point for each transect. An unmarked belt transect was extended parallel to the coast or at a constant depth, while counting each fish observed to cross or within a 2 m wide band (60 m^2). All fish encountered were enumerated, identified to species when possible, and their size (fork length) was visually estimated to the nearest centimeter. Each transect was given a habitat classification based on *in situ* observation following descriptions of benthic habitat maps for the region (NOAA 2001).

In order to determine the distribution of fish throughout their different life stages, the abundance of the most common grunt and snapper species was classified into three groups based on ontogeny. Fork length of each individual observed was used to classify it as early juvenile (E), juvenile (J) or adult (A) based on a range of lengths for each specie's life stage (Table 1.). Individuals greater than the lowest available estimated length at maturity (obtained from the Life-History Tool in Fishbase, Froese and Pauly, 2003) were classified as adults. Those larger than half the size at maturity were classified as juveniles and those measuring less than half the size at maturity were classified as early juveniles.

The median fork length and density for each life stage were compared among habitat types and depth by non-parametric Kruskal-Wallis tests. This allowed the determination of significant differences in the size of fish as well as in the density of each life stage per habitat type throughout Mona Island. Differences within and among habitat types were tested in relation to their grouping in the benthic habitat mosaic of the island. Data were also analyzed with the aid GIS to calculate the magnitude and direction of inferred ontogenetic habitat shifts. In addition this served as an aid for the interpretation of sampling points with similar habitat types throughout the insular platform. This helped identify and quantify critical areas for specific life stages of fish relative to their position on the shelf.

Table 1. Fork length ranges for life stage classification based on size at maturity (Froese and Pauly 2003)

Species	Early Juvenile	Juvenile	Adult
Anisotremus surinamensis	<15	16-30	>31
Haemulon carbonarium	<8	9-15	>16
Haemulon chrysargyreum	<7	8-14	>15
Haemulon flavolineatum	<6	7-12	>13
Haemulon parra	<9	10-17	>18
Lutjanus apodus	<14	15-26	>27
Lutjanus mahogoni	<10	11-20	>21

RESULTS

All sampling was conducted from early August, 2005 to March, 2006 during 11 multiple day expeditions to Mona Island. Data on fish size and abundance was collected snorkeling or with SCUBA between 7:00 am and 5:00pm at 613 sampling sites ranging from 1 to 25 m depth. At least 14 habitat types were classified *in situ*. The total number of fish per 60 m^2 belt transect ranged from 1 to 204. The data on fork length and density of life stages per habitat type is presented separately by each of the grunt and snapper species of Table 1.

Anisotremus virginicus — Significant differences in the size of fish by habitat type (Figure 2) were observed (Kruskal Wallis test p = 0.00). The smallest individuals (10 - 20 cm FL) were found in uncolonized bedrock on rocky shores and small rocky outcrops, while the largest individuals (30 - 45 cm FL) were observed in deeper spur and groove as well as colonized bedrock with boulders. Intermediate sizes (10 - 35 cm FL) occurred in shallow coral reef areas associated to the reef crest or rocky shores. The density of the early juveniles was significantly higher in uncolonized bedrock although early juveniles were also found in rubble and shallow coral, yet absent from other habitats. Juveniles were found in highest densities in shallow coral followed by uncolonized bedrock and patch reefs. Adult densities were high in three high relief habitats (colonized bedrock with boulders, linear reef and spur and groove) but were unobserved in other habitats.

Haemulon carbonarium — This species was the most abundant haemulid throughout Mona Island. Significant differences in fork length by habitat types (Figure 3) were detected (Kruskal Wallis test p = 0.00). The smallest (< 10 cm FL) individuals were found primarily in seagrass with rubble or seagrass with patches followed by uncolonized bedrock and shallow coral. Largest individuals (> 20 cm FL) were found in patch reefs, colonized pavement with sand, spur and groove, linear reef and colonized bedrock with boulders. Intermediate sizes occurred in eight additional habitats including those of the smallest sized fish. Density of early juveniles was significantly higher in seagrass with rubble as well as seagrass with patches followed by uncolonized bedrock and shallow coral. Early juveniles were absent from all other habitats. Juvenile densities were highest in seagrass with patches and uncolonized bedrock followed by shallow coral and three other nearshore habitats. Adults were found in high densities in shallow coral, linear reef, patch reef and colonized bedrock with boulders yet present in 12 of the 14 habitat types available including those where early juveniles were found in high densities. The only habitat types where *H. carbonarium* were not observed were pure seagrass meadows and scattered coral or rock in unconsolidated sediment.

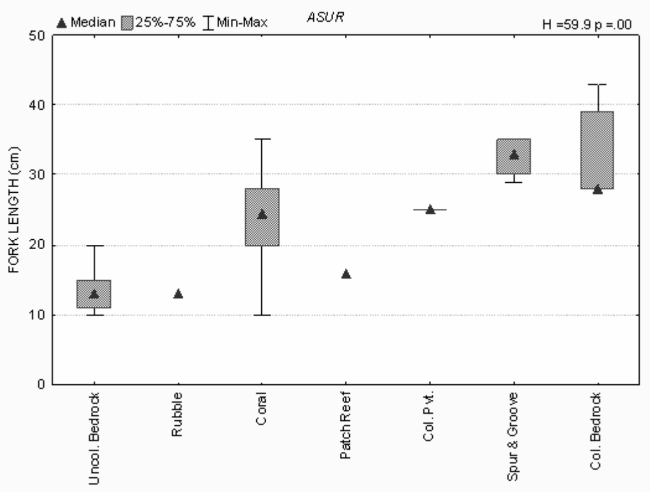

Figure 2. Fish size data for *Anisotremus surinamensis* by habitat type ordered from shore (left) to shelf break (right).

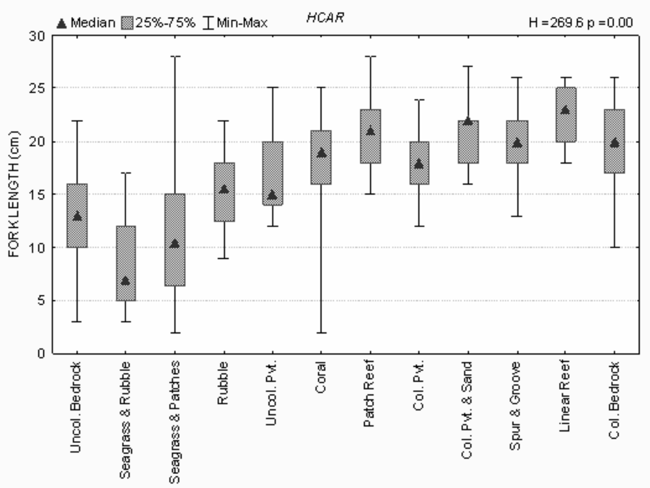

Figure 3. Fish size data for *Haemulon carbonarium* by habitat type ordered from shore (left) to shelf break (right).

Haemulon chrysargyreum: Significant differences in length (Figure 4) were found between the smallest fish in seagrass with rubble and the largest in patch reefs (Kruskal Wallis test p = 0.0001). Fish of a range of sizes were found in four other habitats (uncolonized bedrock, seagrass with patches, uncolonized pavement, and shallow coral). No significant differences were found in the density of early juveniles between habitats where they occurred (uncolonized pavement, seagrass and patches, uncolonized bedrock, shallow coral and seagrass with rubble). Slightly significant (Kruskal Wallis test p = 0.0387) higher densities of juveniles were found in seagrass with patches and shallow coral although they were also found in uncolonized pavement and uncolonized bedrock. Adult densities were significantly higher in shallow coral, seagrass with patches and patch reefs. This species was commonly observed in very large aggregations in high relief habitats provided by live coral such as *Acropora palmata*.

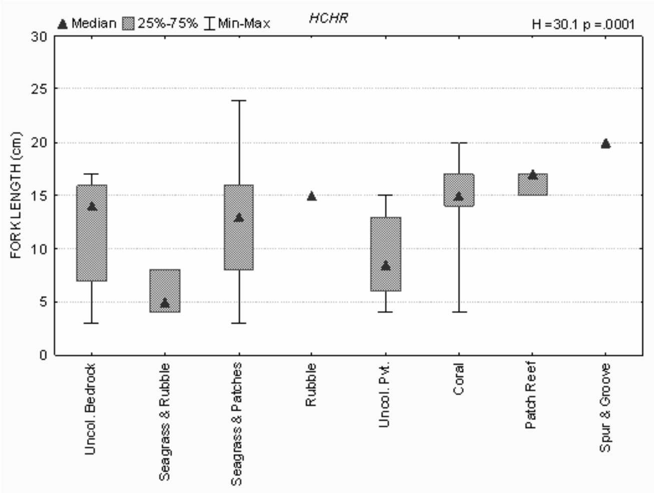

Figure 4. Fish size data for *Haemulon chrysargyreum* by habitat type ordered from shore (left) to shelf break (right).

Haemulon flavolineatum — Significant differences in fork length (Figure 5) were observed between the smaller (< 15 cm FL) sized fish in uncolonized bedrock, seagrass with rubble, seagrass with patches and rubble while larger sized individuals were mostly in uncolonized pavement, colonized pavement, colonized pavement with sand, spur and groove, linear reef and colonized bedrock with boulders. The density of early juveniles was not significantly different among the five habitats where they occurred (seagrass and rubble, seagrass and patches, parch reef, uncolonized bedrock, and rubble). Juveniles were found in significantly highest densities in seagrass with patches, while adult densities were significantly higher in linear reef followed by patch reef.

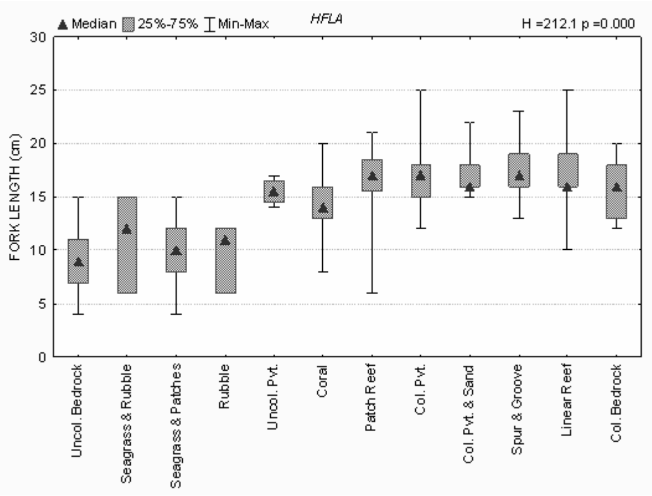

Figure 5. Fish size data for *Haemulon flavolineatum* by habitat type ordered from shore (left) to shelf break (right).

Haemulon parra — Significant differences were observed in fork length (Figure 6) between seagrass and rubble, where the smallest sizes were found, and larger sizes occurred in shallow coral, patch reef, linear reef and colonized bedrock with boulders (Kruskal Wallis test p = 0.00). Intermediate sizes were observed in uncolonized bedrock as well as in seagrass with patches. Density of early juveniles was significantly different between the three habitat types where it occurred (uncolonized bedrock, seagrass with rubble and seagrass with patches). Densities of juveniles remained significantly different, highest in uncolonized bedrock although some additional habitats were occupied (shallow coral, patch reef and rubble). Adult density was highest in patch reef, linear reef, and colonized bedrock with boulders and significantly different than shallow coral and uncolonized bedrock.

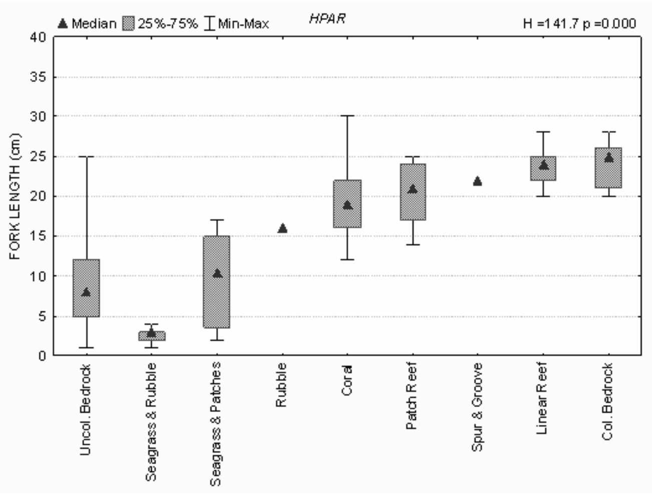

Figure 6. Fish size data for *Haemulon parra* by habitat type ordered from shore (left) to shelf break (right).

Lutjanus apodus — Fish length in seagrass with rubble was significantly smaller (Kruskal Wallis test p = 0.00) than all other habitats (Figure 7). Intermediate sizes were found in uncolonized bedrock while larger sizes were in all other habitats (seagrass and patches, rubble, shallow coral, patch reef, colonized pavement, colonized pavement with sand, spur and groove, linear reef and colonized bedrock with boulders). Density of early juveniles was greatest in uncolonized bedrock, while juveniles were found in 10 different habitats yet significantly higher in colonized bedrock with boulders, linear reef and colonized pavement with sand. Adults were found in highest densities in linear reef and colonized bedrock with boulders.

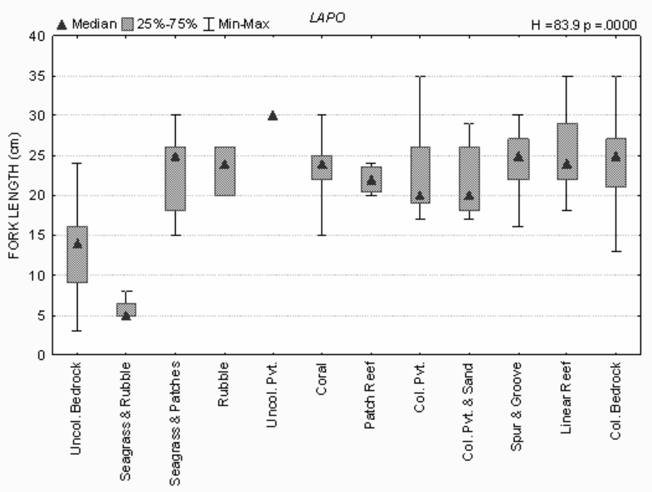

Figure 7. Fish size data for *Lutjanus apodus* by habitat type ordered from shore (left) to shelf break (right).

Lutjanus mahogoni — Fork lengths (Figure 8) were significantly different (Kruskal Wallis test p = 0.00) between the smallest sizes in seagrass with rubble and larger sizes in nine different habitats (seagrass with patches, rubble, uncolonized pavement, coral, patch reef, colonized pavement, spur and groove, linear reef and colonized bedrock with boulders). The density of early juveniles was highest in uncolonized bedrock although also present in seagrass with rubble, patch reef, shallow coral and seagrass with patches. Juveniles were present in 11 habitats although in higher densities in patch reef and shallow coral. The density of adults was highest in shallow coral and patch reef.

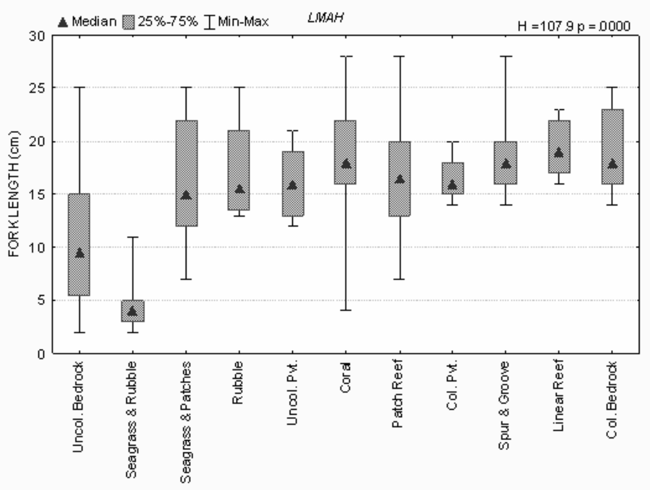

Figure 8. Fish size data for *Lutjanus mahogoni* by habitat type ordered from shore (left) to shelf break (right).

It is notable that the greatest densities for these species occurred in habitats that occur in reduced area. Overall, the greatest density for grunts and snappers occurred in linear reef, colonized bedrock, uncolonized bedrock, patch reef, and seagrass habitats, which amount to 20% of the insular platforms area. These are usually small patches of habitat in the mosaic For example, the total amount of area occupied by the most common grunt species, *H. carbonarium* as early juveniles was 12.8% of the habitat available, for juveniles this increased to 24.2%, and as adults they occupied 69% of the insular platform, although this also varied among fish species.

DISCUSSION

The sizes and densities of the coral reef fishes analyzed here were significantly different from what could be expected randomly. The patterns in fish size class distributions lead us to infer that all species discussed here exhibit ontogenetic migrations from backreef and near shore habitats where early juveniles were found to forereef (and shelf break) habitats where juveniles and adults occurred. Variations in the magnitude and direction of the adult fish distributions were observed at the family level. That is, not all grunt and snapper adults were found equally far although as early juveniles many species co-occurred in specific habitats such as seagrass and shallow coral reefs. The extent as to how far the adults of these species were found from their nursery habitats (where early juveniles were found) also varied at the family level. For example adult *L. mahogoni* was absent in distant, deeper areas where *L. apodus* were frequent, although they co-occurred as early juveniles in shallow habitats.

Coral reef fish nursery areas identified during this study suggests that the relationship of some species to seagrass habitats is less obligate than that described at other locations where mangroves usually occur in conjunction with seagrass (Nagelkerken *et al.* 2000, Aguilar-Perera and Appeldoorn, 2007). *Lutjanus apodus* is commonly found in mangrove habitats as newly settled juveniles (Pollux *et al.* 2007) and has been described as having a high dependence on mangrove and seagrass habitats (Nagelkerken *et al.* 2002), yet they occurred as early juveniles mainly in uncolonized bedrock and seagrass with rubble habitats near shore at Mona Island where mangroves are absent. As adults, *L. apodus* were observed in high relief habitats of deep and distant areas in significant numbers. *Lutjanus mahogoni* on the other hand showed high variability in the occurrence of early juveniles who were found in a wider range of habitats. Dorenbosch *et al.* (2004) also encountered high variability in the occurrence of this species in relation to mangrove and seagrass bays. In Southwestern Puerto Rico shallow coral reefs were an important habitat for juvenile fishes in some cases more than mangroves and seagrass (Aguilar-Perera and Appeldoorn 2007). At Mona Island shallow corals were important habitat for juvenile and adult *A. surinamensis, H. carbonarium, H. chrysargyreum,* and *L. mahogoni* but not so much for the other species studied; therefore, it is important that species be studied individually and not pooled at the family level due to species specific patterns in habitat utilization patterns.

At the species level, the differences in fish length by habitat type and the observed differences in density suggest there are certain combinations of habitats which are essential for each. Depth at which a habitat was found seemed to be an important factor for some species regardless of the availability of similar habitats at other depths. For example, *H. chrysargyreum* and *L. mahogoni* were rarely found in significant numbers in high relief habitats at greater depths, although they exhibited high densities in shallow high relief coral dominated habitats. With these distributions patterns linking specific habitats, we can now trace ontogenetic migrations throughout the insular platform and calculate spatial metrics of these combinations. This preliminary analysis will allow us to test the landscape ecology theory to coral reef fishes at reduced scales with a detailed benthic habitat map, which is in preparation.

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