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Differences in coral-reef fish assemblages between mangrove-rich and mangrove-poor islands of Honduras

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Abstract. Visual surveys of coral-reef fish were conducted on two islands (and associated cays) off the Caribbean coast of Honduras, Cayos Cochinos (mangrove-poor) and Utila (mangrove-rich). Local populations on both islands exploit all marine habitats, and Utila suffers from higher fishing pressure compared to Cayos Cochinos, the latter having a conservation plan and no-take zones. Nine sites were visually surveyed in the mangroves to identify nursery species. Coral reef surveys consisted of eight randomly selected 50m transects at each site (six sites per island) where fish abundances, microhabitat percent cover, and rugosity were recorded. Findings from this study reveal that adult coral-reef nursery fish assemblages differ between the two islands. Out of 13 coral-reef fish whose juveniles are found in mangroves but absent from reefs, eight species had significantly higher adult coral-reef fish abundances on Utila than Cayos Cochinos. Canonical Correspondence analysis found that rugosity and percent algae explained a small but significant variation in fish assemblages. This correlation most likely explains the occurrence of increased adult non-nursery species abundance on Utila. However, a higher percentage of adult nursery species (compared to non-nursery species) had higher abundances on the surrounding reefs of Utila indicating the importance of the presence of mangroves.

Key words: Coral-reef fish, Mangroves, Nursery, Microhabitat.

Introduction

Shallow marine biotopes are thought to act as nurseries for many species of tropical fish (Dahlgren et al. 2006). Nurseries are believed to disproportionately enhance numbers of juveniles that move into adult habitats (Beck et al. 2001). Nursery reef fish species are species that are obligate to habitats other than coral reefs while in the juvenile stage. Studies have shown that mangrove and seagrass habitats provide vulnerable newly settled fish with appropriately sized food and refuge from predators (Laegdsgaard and Johnson 2001; Verweij et al. 2006).

Studies have focused on juvenile fish assemblages in mangroves and seagrass beds (Nagelkerken et al. 2000; Dorenbosch et al. 2006; Hindell and Jenkins 2004; Lugendo et al. 2006), and very few have actually compared adult populations in areas with and without mangrove nurseries (Nagelkerken et al. 2002; Mumby et al. 2004).

Past mangrove studies in the Caribbean have made pair-wise comparisons between two islands (mangrove-rich vs. mangrove-poor), to indicate the importance of mangroves as nursery sites. Island comparisons have shown higher abundances of nursery species on islands inhabited by mangroves (Nagelkerken et al. 2002; Mumby et al. 2004).

The aim of this study is to find which coral-reef fish juveniles reside in Honduran mangroves, and to compare these nursery species with control species (non-nursery) abundances between mangrove-rich and mangrove-poor islands. Previous studies have identified covarying factors that influence reef fish populations such as size of coral reefs and dominant coral species; however, this is the first study to include microhabitat variables of reef structure in influencing the adult fish structure. By including these variables, it will be possible to better isolate the importance of mangrove nursery grounds in determining adult reef fish populations.

Material and Methods

Study Area

Sampling and surveying were conducted on the surrounding reefs and mangroves of Utila, Bay Islands and the Cayos Cochinos Islands (Cayos C.), Honduras (Fig. 1). Utila, which has 13 cays, is the southernmost island in the Bay Island archipelago and is located 29 km off the coast of Honduras. Utila is dominated by mangroves (nearly 66% coverage). The mangroves, *Rhizophora mangle* and *Avicennia germinans,* dominate two large lagoons on the south side and mangrove stands on the north side of the island.

Cayos C. consists of Cayos Menor, Cayos Mejor and 13 smaller coral cays. The islands are located southeast of the Bay Islands, 18.5 km from the mainland. Tropical forests cover both Cayos Menor and Mejor, while most of the cays are sandbars. In contrast to Utila, Cayos C. has a distinct absence of mangrove lagoons and supports only two very small mangrove stands with lengths of 100 and 150 meters.

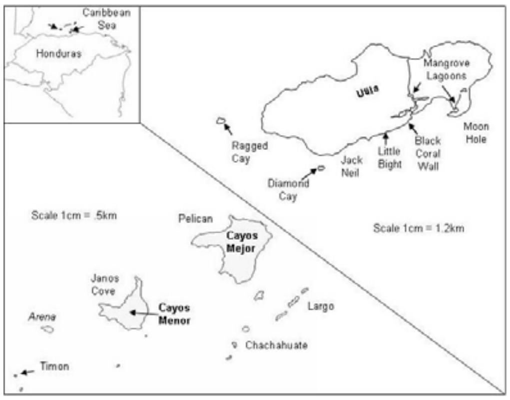

Figure 1: Map of Utila and Cayos Cochinos, Honduras, showing the 12 sites surveyed.

Fish surveys on coral reefs

This study used underwater visual census to make relative comparisons of fish abundances on both islands. Six sites per islands (Utila and Cayos C.) were surveyed. Sites were chosen based on three conditions (1) varying distance to mangroves, (2) reef flat shallower than nine meters (to eliminate any effects depth may have on fish assemblages), and (3) reef large enough to encompass replicate transects.

Within each site, eight non-overlapping 50 meter transects were laid out randomly (separated by >10m). Perpendicular distance and direction between transects were predetermined using random numbers. Each transect was laid out parallel to the reef wall, ensuring that the tape remained within a depth range between four and nine meters (local reefs form walls at depths greater than nine meters). Divers waited five minutes after deploying the tape for the fish to resume normal activity before beginning the survey (Tolimieri 1995). All fish (classified into life history stages), with the exception of small cryptic fish (e.g. gobies and blennies), were visually surveyed within one meter on each side of the tape (total width of 2m) and 2.5 meters above the tape. Life history stages (juvenile vs. adult) were defined by de la Moriniere et al. (2003) and FishBase (2008) (1/3 max adult size), while the initial phase stage was defined by distinct coloration differences (Humann and Deloach 2002).

Lutjanid, Chaetodonid, Haemulid, Scarid, and Serranid adults (large fish or fish with large home ranges) were resurveyed using a larger transect of five meters width. Previous to the study, divers spent two weeks practicing fish identification and experimenting with different transect areas to improve survey accuracy. Multiple divers were used only after survey records matched principle diver's records. Sites surveyed were rotated, to randomize diurnal and lunar variables. All surveys were performed between 0900 and 1600 to ensure consistency in fish activity and presence (Colton and Alevizon 1981).

Fish surveys in mangroves

To establish which coral-reef species use mangroves as a juvenile nursery (aka nursery species), nine mangrove sites (one on Cayos C., two on the northside of Utila, and six in Utila's western mangrove lagoon) were visually surveyed using snorkeling gear. In each site, 30x1m transects, with 10 meters separation, were measured out and marked with flagging tape before surveying.

Habitat and Rugosity

In order to provide insight into other potential mechanisms underlying anticipated differences in the fish communities between islands, microhabitat characteristics within every transect were measured using the point-contact technique (Caselle and Warner 1996). At every one meter interval on the tape, substrate type was recorded and live habitat was identified to species level (soft coral and algae were only identified to genus level due to lack of taxonomy expertise). Non-living habitat was recorded as sand, dead coral, or coral rubble (broken coral, mostly *Acropora* spp.)

Rugosity, a measure of the variation in height of physical surfaces along a linear extent of habitat, is often employed as one of the most important measurements of habitat complexity. On each transect, rugosity was measured using the traditional chain-transect method, laying a chain over the contours of the reef and measuring the resulting length (Risk 1972). The chain-transect rugosity is the ratio of contoured distance to the linear distance.

Analysis

Coral-reef fish assemblage of Utila and Cayos C. was analyzed using a Bray Curtis multivariate scatterplot and ANOSIM analysis from Community Analysis Package (Copyright Pisces Conservation LTD) statistical software. Data were first square-root transformed.

Fish abundances were statistically compared between Cayos C. and Utila. Comparisons were made using SPSS statistical software; a Mann-Whitney U-test was used on square-root transformed data.

One-way ANOVA, without data transformation was used to compare rugosity and microhabitat percentages between the two island sets. In the case of significance, Bonferroni post-hoc tests were used to compare between sites. Canonical Correspondence analysis (CCA) and Monte Carlo tests (Environmental Community Analysis, Copyright Pisces Conservation LTD, statistical software) were used to compare microhabitat percent cover and rugosity to fish assemblages. To compare rugosity and microhabitat with abundances of individual fish species, Spearman-ranked correlations (SPSS) were used.

Results

Comparison of adult coral-reef fish assemblages between islands

Utila and Cayos C.'s multivariate plots of assemblages of fish nursery species on coral reefs show a significant difference (Fig. 2, ANOSIM, $p < 0.001$, $R = 0.104$) between the two islands.

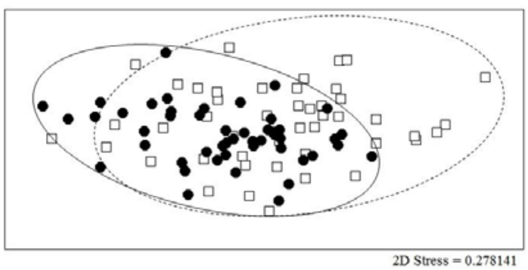

Figure 2: Multidimensional scaling ordination plot (Bray-Curtis dissimilarity coefficient) of fish assemblages (adult nursery species on coral-reefs) on Utila and Cayos C.
(□: Cayos Cochinos, ●: Utila).

Comparisons of average adult abundances on coral reefs (data from 5m transect width)

Of the 13 nursery species whose juveniles were found primarily in mangroves, eight fish species had significantly higher abundances on mangrove-rich Utila's coral reefs (Fig. 3). These species include butterflyfish *Chaetodon striatus* ($p < 0.01$), *C. capistratus* ($p < 0.01$), and *C. ocellatus* ($p < 0.001$), the parrotfish *Sparisoma chrysopterum* Initial Phase ($p < 0.05$), the snapper *Lutjanus apodus* ($p < 0.001$) and grunts *Haemulon carbonarium* ($p < 0.001$), *H. flavolineatum* ($p < 0.001$), and *H. sciurus* ($p < 0.001$).

These trends were present when broken down to site-to site comparisons. For seven species with significantly higher abundances, at least two sites on Utila (actual sites differed per species) had significantly higher abundances than three sites on Cayos C. ($p < 0.05$). *C. striatus* was the only species whose abundance showed no significant difference between Utila and Cayos C.'s individual sites.

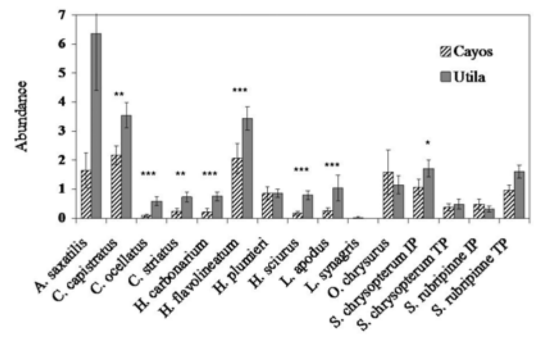

Figure 3: Average abundance per transect (±SE) of adult coral-reef fish whose juveniles were found in the mangroves. (*: p<.05; **: p<.01; ***: p<.001) (IP: Initial Phase; TP: Terminal Phase).

Comparing non-nursery and nursery species between islands

Some non-nursery adult fish species had higher abundances on Utila as well. However, a larger percentage of nursery species than non-nursery species had higher abundances on Utila (Fig. 4)

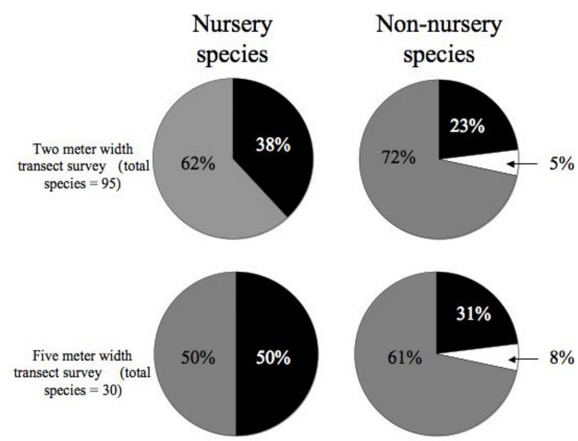

Figure 4: Pie charts depicting nursery and non-nursery fish abundance percentages for both the two meter and five meter width transect surveys (■ Percent species whose abundances were significantly higher on Utila , □ abundances lower on Utila, ■ No significant difference in abundances between Utila and Cayos C.)

Coral Reef Microhabitat and Rugosity

The point-contact microhabitat survey resulted in nine genera of algae, 13 genera of sponges, 17 genera of live hard coral, and eight genera of soft coral. Algae covered the largest percentage (Cayos C.: 40%; Utila: 33%) of transects on both islands; *Lobophora, Dictyota,* and *Halimeda* spp. dominated. Cayos C. had a significantly higher percentage of algae than Utila ($p < 0.05$), while Utila had a significantly higher percent cover of non-living coral than Cayos C. ($p < 0.001$). Percent cover of hard coral and soft coral, approximately 17% and 12% respectively, was not significantly different between the islands.

Average rugosity ratios for Utila and Cayos C. were 1.37 (SE ± 0.4) and 1.41 (SE ± 0.03), respectively. Ratios between islands were not significantly different (p = 0.370). In addition, variation in depth (4-9m) produced no significant effects on fish assemblages.

Canonical Correspondence Analysis showed that algae (4.98% of variance) and rugosity (4.45% of variance) were the two best explanatory factors explaining variability in fish assemblages (see Fig. 5 for the ordination plot). Monte Carlo randomization tests demonstrated that the plotted axes were significant at the 0.05 level.

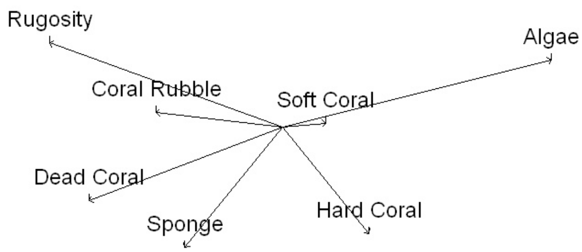

Figure 5: Canonical Correspondence Analysis Ordination plot of environmental vectors in correspondence to adult nursery fish assemblages. Length of vectors represents strength of explanatory variable, while direction of vector shows positive/negative correlation with other vectors.

Spearman-Ranked Correlations on substrate composition and rugosity did not reveal any clear correlations between these explanatory measurements and "mangrove-dependent" fish abundances with the exception of *Abudefduf saxatilis* (Utila and Cayos *C. p* < *0*.051).

Discussion

Comparison of adult coral-reef fish assemblages between islands

Studies in Belize and Mexico found that the structure of Caribbean reef fish communities on reefs was significantly different between mangrove-rich and mangrove-poor sites (Mumby et al. 2004). These authors concluded that mangroves were the "dominant factor structuring reef fish communities."

Furthermore, the presence of mangroves in the Belize/Mexico studies were significantly correlated with the biomass of six species. *Scarus iserti* (striped parrotfish), *Haemulon sciurus* (blue-stripped grunt), *Haemulon flavolineatum* (French grunt), *Haemulon plumieri* (white grunt), *Ocyurus chrysurus* (yellow-tail snapper) and *Lutjanus apodus* (schoolmaster grunt) had biomass increases > 42% (Mumby et al. 2004). Two other studies have surveyed fish on coral reefs in the presence/absence of mangroves. In a study performed by Dorenbosch et al. (2003), sites adjacent to seagrass/mangrove bays had significantly higher densities of *H. sciurus, O. chrysurus* and *L. apodus.* Nagelkerken et al. (2002) compared fish assemblages on islands with and without nursery lagoon; *H. sciurus*, *O. chrysurus, L. apodus,* and *S. iserti* were highly dependent on mangrove nurseries. Likewise, the current study found significantly higher abundances of *H. sciurus, H. flavolineatum,* and *L. apodus* on Honduran reefs adjacent to islands with mangroves (Utila). *L. apodus* was the most common juvenile species found in the majority of mangrove studies performed in the Caribbean; therefore, mangroves have been deemed a vital habitat for this species (Nagelkerken et al. 2000; de la Moriniere 2003; Chittaro et al. 2005; and Verweij et al. 2006).

Since approximately 50% of the juveniles of *S. iserti* were found on coral reefs (53% on Cayos C., 40% on Utila) (data from surveys of 2m width transects), it was not considered to be a nursery species. Unlike previous studies, *S. iserti* adults were not found to have higher densities on mangrove-rich sites. In fact, their abundances were significantly lower at coral reef sites near mangroves.

Although Nagelkerken et al. (2002) concluded that *Chaetodon capistratus* and *Sparisoma chrysopterum* did not depend on mangroves, the present study found significantly higher abundances on Utila's coral reefs. Therefore, the dependence of these two species on mangrove nurseries is not a fixed factor. The current study also found significantly higher abundances of both *Chaetodon striatus* and *C. ocellatus* adults on the Utila. Nagelkerken et al. (2002) did not survey these two species. Nursery species *Abudefduf saxatilis, Haemulon plumieri,* and *Ocyurus chrysurus* were not significantly different between islands.

Coral-reef fish abundance explanatory variables

Although this study focuses on the positive effects mangroves have on nursery species abundances, many different explanatory variables (fishing pressures, rugosity, microhabitat, recruitment differences) may affect fish assemblages. Although local artisanal fishermen fish on both Cayos C. and Utila, Cayos C. has reduced fishing pressure due to a marine reserve conservation plan therein. On Cayos C., commercial fishing is illegal, fishing gear is regulated, and no-take zones have been established (Clifton and Clifton 1998). Therefore, it is unlikely that fishing pressure can explain decreased fish abundances on Cayos C.

In some studies, percent cover of live coral showed a significant positive correlation with fish species richness and abundance on shallow coral flats (Bell and Galzin 1984; Chabanet et al. 1997; Garpe and Ohman 2003). The current study, however, did not find a significant difference in live hard coral (average percent cover or species richness) between islands or within sites. Therefore, this variable was not an important determinant of fish numbers.

However CCA ordination analysis shows that algae, which was significantly higher on Cayos C., and rugosity affect the nursery fish assemblages. In addition, results of the present study showed that the nursery species *Abudefduf saxatilis* was negatively correlated with algae on coral reefs. Further research must be implemented to study the negative correlation between *A. saxatilis* and algae.

Seven non-nursery species experienced higher abundances on Utila than Cayos C., which may be a result of these other explanatory variables. Regardless, it is important to emphasize that a larger percentage of nursery species had higher abundance on Utila than did non-nursery species. Therefore, comparisons between coral reefs off of mangrove-rich islands and mangrove-poor islands indicate that mangroves may increase the abundance of nursery coral-reef fish. This study adds one data point (island comparisons of fish nursery species) to a large scale graph of comparable matched-pairs from prior studies (four studies finding positive correlations between mangroves and adult coral reef fish and two showing no correlation (Halpern 2004, Nagelkerken 2007)) to give statistical power to comparing fish assemblages in the presence/absence of mangroves.

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