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L. K. B. Jordan
Nova Southeastern University

David S. Gilliam
Nova Southeastern University, gilliam@nova.edu


Robin L. Sherman
Nova Southeastern University

Paul T. Arena
Nova Southeastern University, arenap@nova.edu

Fleur M. Harttung
Nova Southeastern University

See next page for additional authors

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Authors

L. K. B. Jordan, David S. Gilliam, Robin L. Sherman, Paul T. Arena, Fleur M. Harttung, Robert M. Baron, and Richard E. Spieler

Spatial and Temporal Recruitment Patterns of Juvenile Grunts (*Haemulon* spp.) in South Florida

LANCE K.B. JORDAN¹, DAVID S. GILLIAM^{1,2}, ROBIN L. SHERMAN^{2,3},
PAUL T. ARENA¹, FLEUR M. HARTTUNG¹, ROBERT M. BARON¹,
and RICHARD E. SPIELER^{1,2,4}

¹*Oceanographic Center*

²*National Coral Reef Institute*

³*Farquhar College of Arts and Sciences*

⁴*Guy Harvey Research Institute*

Nova Southeastern University

Ft. Lauderdale, Florida 33314 USA

ABSTRACT

Grunts (Haemulidae) are important fisheries species and represent a major component of reef fish communities in the Greater Caribbean region. To date, little is known about their recruitment patterns. Data from more than 2,000 visual fish counts from multiple natural and artificial reef studies in Broward County, Florida, over a seven-year period, were examined to identify both spatial and temporal trends in recruitment of juvenile (*i.e.*, < 5cm TL) grunts of the genus *Haemulon*. In general, data from these studies indicate that juvenile *Haemulon* spp. recruitment increases in the spring and peaks in the early summer months (*i.e.*, June and July). Data from natural reef surveys revealed a predominantly nearshore preference for recruitment in water depths less than 8 m. However, on artificial reefs, recruitment commonly occurred at 20 m depths. The biotic and abiotic factors determining the settlement of grunts are not clear and will be examined in future studies.

KEY WORDS: Recruitment, Reef Fish, Visual Census

Patrones Espaciales y Temporales en el Reclutamiento de Juveniles de Roncos (*Haemulon* Spp.) en el Sur de Florida (Estados Unidos de América)

Los roncós (Haemulidae) son especies importantes en las industrias pesqueras del Caribe. Poco se sabe acerca de sus patrones de reclutamiento. Este estudio examinó los patrones espaciales y temporales en el reclutamiento de juveniles de *Haemulon* spp. (< 5cm TL) en el condado de Broward, Florida. Los datos indicaron que el reclutamiento máximo ocurrió durante el comienzo del verano (*i.e.*, junio y julio). Los resultados también mostraron que en arrecifes naturales, el reclutamiento de *Haemulon* spp. ocurrió en densidades más altas en los sitios más cercanos a la orilla. En los arrecifes artificiales, el reclutamiento de *Haemulon* spp. también mostró una preferencia por las zonas poco profundas.

PALABRAS CLAVES: Reclutamiento, roncós, *Haemulon* spp.

INTRODUCTION

Grunts (Haemulidae) represent a substantial, and in some cases dominant, component of Greater Caribbean reef fish assemblages. Three genera comprise the family Haemulidae in the western Atlantic: *Haemulon*, *Anisotremus*, and *Orthopristes*. Of these, *Haemulon* is the most speciose genus with 15 western Atlantic species (Froese and Pauly 2002). This genus is also more frequently encountered in South Florida than the other two genera (Stark and Davis 1966). Although the ecology and behavior of adult *Haemulon* spp. have been documented, little is known about their settlement strategies.

Like other fishes that associate with coral reefs, *Haemulon* spp. have a pelagic larval stage, followed by demersal juvenile and adult stages. Pelagic larval duration is shorter compared to many other reef fish genera, with one species, the French grunt (*Haemulon flavolineatum*), settling 15 days after hatching (McFarland et al. 1985). Settlement for this genus has been recorded on a variety of habitats including mangroves, seagrass beds, patch reefs, wormrock, low relief nearshore hardbottom, and artificial reefs. After settlement, newly settled (< 2cm) juveniles often live within multicohort, congeneric schools feeding on plankton and trying to avoid the most common fate of mortality due to predation (McFarland 1980, Shulman and Ogden 1987). Newly settled *Haemulon* spp. are difficult to identify to species level because of similar pigmentation patterns (Lindeman 1986). If newly settled individuals survive the intense predation pressure, they will grow, enter the early juvenile stage (~2-5cm), and undergo an ontogenetic shift in habitat use and feeding behavior. Early juveniles no longer feed exclusively on plankton. They forage on infaunal and epifaunal invertebrates (though exceptions exist) and, presumably as a result, begin to develop adult coloration patterns (Lindeman 1986). It has also been suggested that this ontogenetic change in feeding behavior is associated with a relatively short migration to a different habitat (Lindeman 1986). Once adult pigmentation patterns begin to emerge, *Haemulon* spp. may migrate further offshore to deeper waters or continue to live as a member of the shallow reef community (McFarland and Wahl 1996).

This paper examines the temporal and spatial recruitment patterns of juvenile *Haemulon* spp. in Broward County, Florida. Data analyzed for this paper were compiled from data acquired in four previously published studies on both natural hardbottom and artificial reef modules. All four studies were designed to test specific hypotheses, which focused on total fish assemblages (including all species). These studies were not designed to examine species-specific differences amongst the haemulids. Due to the difficulty of identifying newly settled and early juveniles and the time constraints placed on observers using SCUBA, all species in the genus *Haemulon* were grouped together in these studies. The present work was designed as a preliminary examination of *Haemulon* spp. recruitment in general to gain insight for the design of a focused, hypothesis-directed investigation of the species-specific cross-shelf spatial patterns of *Haemulon* recruitment.

METHODS

Data from four separate studies in Broward County, Florida were used to examine the local spatial and temporal patterns of juvenile *Haemulon* spp. abundance. Because of the unique ontogenetic shift in habitat use and feeding behavior fishes of this genus undergo, data were analyzed, where applicable, in terms of two life stages: newly settled individuals (< 2cm TL) and early juveniles (2 - 5 cm TL). Of the four separate studies included in this analysis, three examined artificial concrete reef modules (Reefball[®], Gilliam-Spieler [hereafter GS] modules, and Isolation studies) and one examined natural hardbottom. One study used replicate Reefball[®] molds to construct replicate patch reefs. For the present study, data collected monthly from ten Reefballs ("pallet balls", 1.3 m x 1 m) deployed on a sand flat at 21 m were compared to ten deployed at 7 m depth over 18 months from April 1995 to October 1996 (Sherman et al. 2002). No data were collected in October 1995 due to rough sea conditions. For the GS module (aka Fish Condo) study, replicate 1 m³ modules were constructed using concrete block amalgamated with waste concrete and rebar. Ten GS modules deployed at 21 m and ten at 7 m depth were censused monthly from January to October 1996 (Gilliam 1999, Sherman 2000). The Isolation study, which examined the effects of reef isolation distance on the associated reef fish assemblage, also used GS modules as replicate patch reefs (Jordan 2002, Jordan et al. in prep.). Modules were positioned at the apices of four equilateral triangles with side lengths of: 0.33 m, 5 m, 15 m, and 25 m; each with two replicates. Two additional treatments were used here to examine the effects reef size (i.e., volume): a solitary module and two modules side by side. The Isolation study was performed at only one depth (7 m) and only used to examine temporal trends in *Haemulon* spp. abundance. In the three studies using artificial reef modules, data were collected by recording the abundance of every species present within one meter of the modules. Then, each fish was assigned into one of five size classes based on total length (TL): < 2 cm, 2 - 5 cm, 5 - 10 cm, 10 - 20 cm, and > 20 cm. For this paper only, *Haemulon* spp. from the smallest two size classes were extracted from the data sets.

Data from the fourth study were collected using a different visual census technique. The Natural Hardbottom study used the Bohnsack and Bannerot (1986) point-count method as the census technique. In this method a diver remains stationary at the center of a 15 m diameter cylinder that extends from the bottom to the surface. During the initial five minutes, all species present within the cylinder are recorded. When the five minutes have passed, the abundance of each species present in the cylinder is recorded and, for all species, a mean, minimum and maximum total length (cm TL) were assigned. For the purpose of the present study, only juvenile *Haemulon* spp. with a maximum size of 5cm TL were analyzed from 483 point-counts. The three reef tracts in Broward County, Florida, USA, run parallel to the coastline in sequentially deeper water separated by sand. The Inshore reef ranges from 3 m to 5 m depth while the Middle reef crests at 5 m and extends down to 20 m depth. The crest of the Offshore reef is at 15 m with the eastern edge reaching past 30 m depth. Point-counts were performed on the crest, eastern, and western

edges of each of the three reef tracts making a cross-shelf transect with nine point-counts each. Transects were separated by 0.463 km (0.25 nautical miles) (see Ettinger et al. 1999 for a full description of the study site). The Deep GS and Deep Reefball module sets were deployed in the sand flat separating the Middle and Offshore reef tracts while the Shallow GS, Shallow Reefball, and Isolation study modules were deployed in the sand flat between the Inshore and Middle reef tracts.

Due to the diverse methodologies among studies the data were not combined; data from each study were analyzed separately. Prior to ANOVA tests, abundance data were examined to see if they significantly differed from a normal distribution. If found to be non-normal, data were $\log_{10}(x+1)$ transformed to homogenize variances. A one-way parametric ANOVA was then performed. If significant differences ($\alpha = 0.05$) were found, a *post hoc* Newman-Keuls test was used to identify the differences among means. A T-test for dependent samples was performed to compare the abundances of newly settled individuals and early juveniles (Statistica v6, Softstat, Inc. 2001).

RESULTS

Spatial Distribution

Reefball Study — In this study (April 1995 - October 1996), comparison between Shallow (7m depth) and Deep (21 m depth) sets of modules showed the Shallow set had a significantly greater abundance of newly settled individuals (< 2 cm TL) than the Deep set of modules (Shallow: 10.39 ± 1.87 , Deep: 3.35 ± 1.01 [mean \pm 1 SE]). However, when early juvenile (2 - 5 cm TL) abundance was compared between the same sets of modules, no significant differences arose (Shallow: 3.13 ± 1.06 , Deep: 0.80 ± 0.25 [mean \pm 1 SE]).

Gilliam-Spieler (GS) Modules Study — This study (Jan-Oct 1996) compared fish assemblages at two depths, GS modules demonstrated no significant differences in abundance of newly settled *Haemulon* spp. when comparing sets of modules at 7m and 21 m depth (Shallow: 6.67 ± 1.78 , Deep: 12.10 ± 6.01 [mean \pm 1 SE]). When the early juvenile abundance was compared among the same sets of modules at differing depths, the 7 m depth set had a significantly higher abundance than the modules at 21 m depth (Shallow: 20.85 ± 4.06 , Deep: 16.17 ± 4.61 [mean \pm 1 SE]).

Natural Hardbottom Study — Analysis of juvenile *Haemulon* spp. (< 5cm TL) data from natural reef sites (Aug 1998 - May 2002) revealed a distinct spatial pattern. Juvenile *Haemulon* spp. abundance appeared to decrease away from shore. The Inshore reef tract had significantly more juvenile *Haemulon* spp. than both the Middle and Offshore reef tracts, which lacked significant difference from one another (Figure 1). With the three reef tracts separated into their respective census sites (i.e., western reef edge, reef crest and eastern reef edge), creating a more

detailed representation of the shelf profile, the apparent trend of decreasing *Haemulon* spp. abundance moving offshore was again present. The most nearshore site, the western edge of the Inshore reef (referred to as the Inshore West site), had significantly more juvenile *Haemulon* spp. than any other census site (Fig. 2). The other two Inshore reef census sites (Inshore Crest and Inshore East sites) had a significantly higher abundance than the remaining Middle and Offshore reef census sites, which lacked difference from one another. In fact, of the 320 censuses performed on the Middle and Offshore reef tracts, juvenile *Haemulon* spp. were recorded during only 11 counts: six times on the Middle West, three times on the Middle Crest, once on the Middle East and Offshore East, and never on the Offshore West and Offshore Crest census sites.

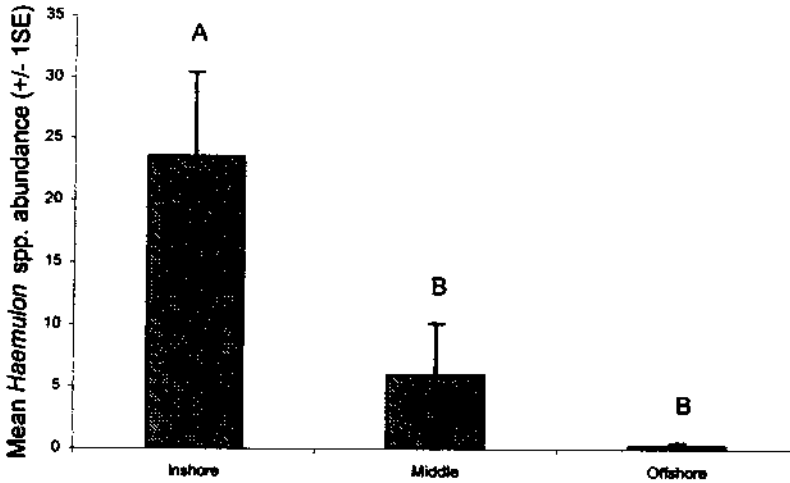


Figure 1. Mean abundance of juvenile (< 5 cm TL) *Haemulon* spp. on the three natural reef tracts when pooling all reef census sites. Newman-Keuls grouping letters that are the same are not significantly different ($p > 0.05$).

Temporal Distribution

Reefball Study — Both newly settled and early juvenile *Haemulon* spp. abundance appeared to be higher in the summer. Although significantly different, pooling data from Deep (21m depth) and Shallow (7m depth) sets of modules suggested that, with few exceptions, newly settled individuals were normally more abundant than early juveniles (Figure 3). This was substantiated by a T-test for dependent samples

($p < 0.05$). In fact, early juvenile abundance was qualitatively higher in only three of a possible 18 months: August 1995, March 1996, and October 1996. The opposite was found on the GS modules (see below). For the GS module study, early juvenile abundance was significantly higher than newly settled individual abundance (T-test for dependent samples).

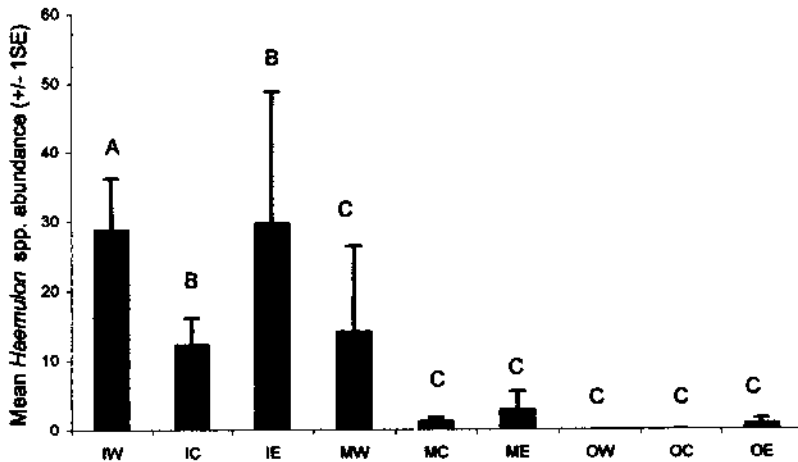


Figure 2. Mean abundance of *Haemulon* spp. juveniles (< 5 cm) on reef census sites: IW = western edge of Inshore reef, IC = crest of Inshore reef, IE = eastern edge of Inshore reef, MW = western edge of Middle reef, MC = crest of Middle reef, ME = eastern edge of Middle reef, OW = western edge of Offshore reef, OC = crest of Offshore reef, OE = eastern edge of Offshore reef. Newman-Keuls grouping letters that are the same are not significantly different ($p > 0.05$).

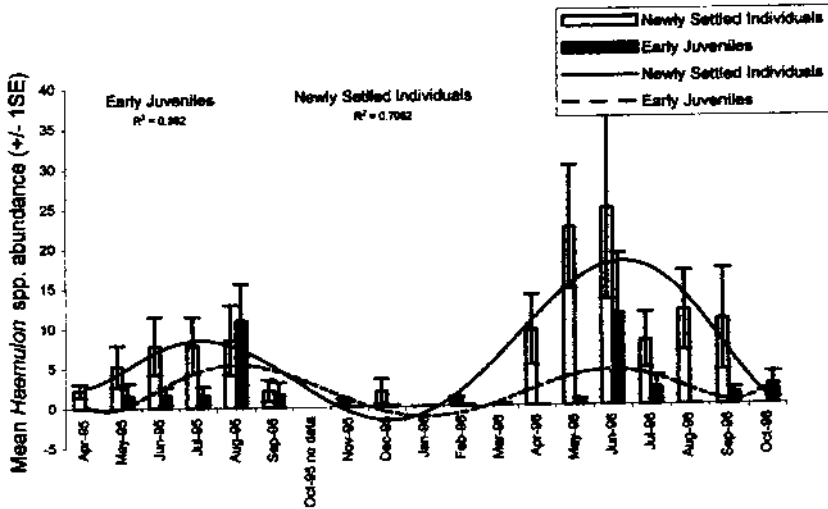


Figure 3. Monthly mean abundance of newly settled and early juvenile *Haemulon* spp. on Reefball modules pooling Deep (21 m) and Shallow (7 m) sites.

Gilliam-Spieler (GS) Module Study — As mentioned above, the abundance of newly settled individuals lacked significant differences between Deep and Shallow module sets. When pooling these data, the abundance of newly settled fishes exhibited a significantly smaller magnitude than early juveniles (T-test for dependent samples) and lacked significant differences among months (Figure 4). In contrast, early juvenile abundance exhibited significant differences between the module sets at differing depths. Nevertheless, when pooling these data, early juvenile *Haemulon* spp. abundance on the Deep set of modules appeared to exhibit a pattern similar to the Shallow set of modules, although the summer abundance increase was more precipitous (Figure 5). From May to June 1996, early juvenile abundance increased from means 0.10 to 81.00, respectively. After June, abundance gradually decreased.

Isolation Study — In Jordan and coauthors (in prep.), significant differences were found for the abundance of newly settled individuals but not for early juveniles among treatments with different amounts of isolation distance separating the three modules. However, when pooling all isolation treatments by month, significant differences occurred for both newly settled and early juvenile abundances. Using pooled data from different treatments likely increased the variability of the monthly means; nevertheless, temporal trends appeared to exist for both life history stages (Figure 6). During 1999, the abundance of newly settled individuals appeared to be higher from May to July. In 2000, abundance appeared to increase in late winter/early spring, peaking in March. At the end of this study, the abundance of newly settled individuals again increased from July to September, suggesting another

large settlement pulse. Early juveniles also appeared to exhibit a temporal trend in abundance. Although present for every monthly data collection, the abundance of early juveniles increased in the spring months, and peaked in the summer months (*i.e.*, June, July, August). Examination of 2000 data revealed an increase in early juveniles coinciding with a decrease in newly settled *Haemulon* spp. This apparent temporal lag between newly settled and early juveniles may be the result of transition of newly settled individuals into early juveniles. As newly settled individuals grew past 2 cm TL, they entered the early juvenile size category. However, this transition alone could not account for the abundance increase of early juveniles considering peak early juvenile abundance is substantially greater than the peak abundance of newly settled individuals.

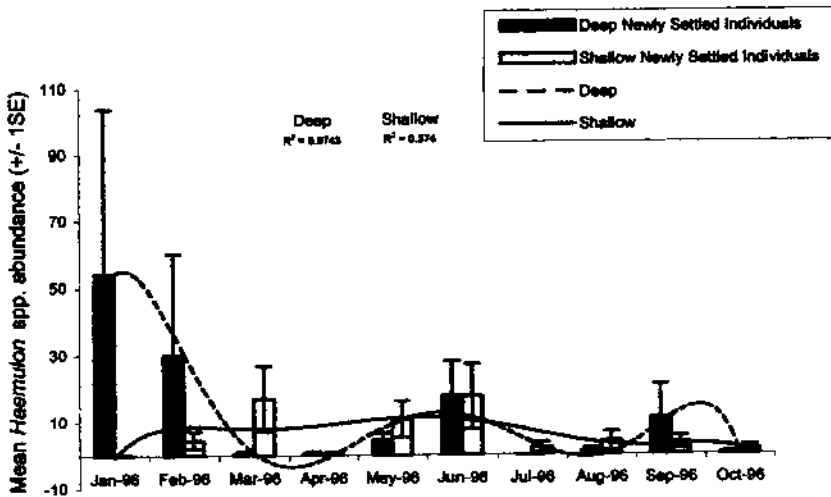


Figure 4. Monthly mean abundance of newly settled *Haemulon* spp. on Gilliam-Spieler modules deployed at Deep (21m) and Shallow (7m) sites.

Natural Hardbottom Study — Locating temporal trends in abundance of juvenile *Haemulon* spp. (< 5cm TL) is problematic in the Natural Hardbottom study data. The data were collected sporadically during the year with the majority taken during summer months, nor was sampling effort evenly divided among the three reef tracts throughout the year. Regardless of these obvious sources of error, juvenile *Haemulon* spp. abundance appeared to be lower in winter months and higher in spring and summer months (Figure 7). Although not substantiated by ANOVA, this temporal trend appears consistent with the findings from the other studies.

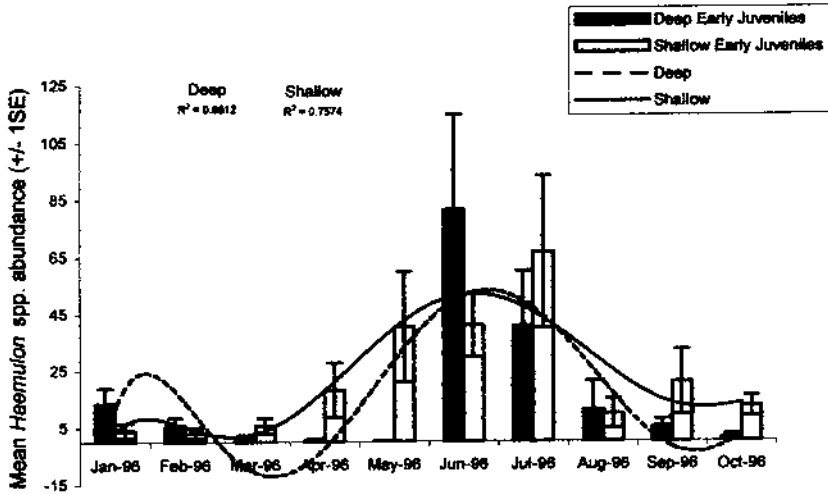


Figure 5. Monthly mean abundance of early juvenile *Haemulon* spp. on Gilliam-Spieler modules deployed at Deep (21m) and Shallow (7m) sites.

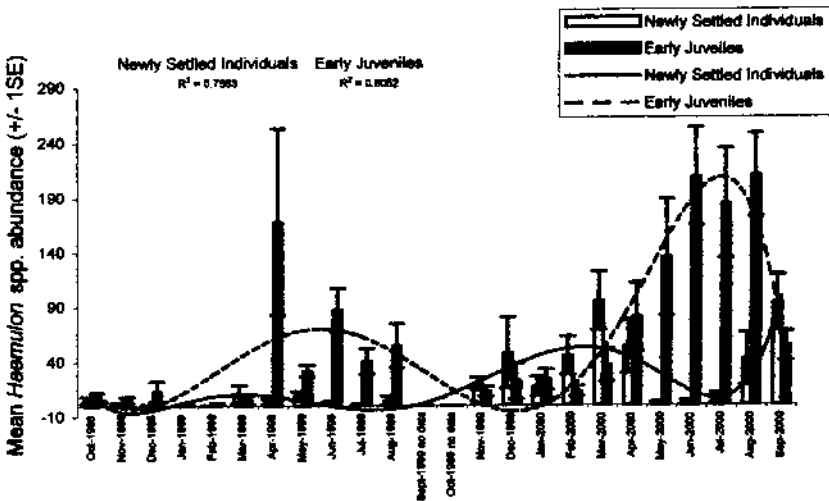


Figure 6. Monthly mean abundance of newly settled and early juvenile *Haemulon* spp. on Isolation study.

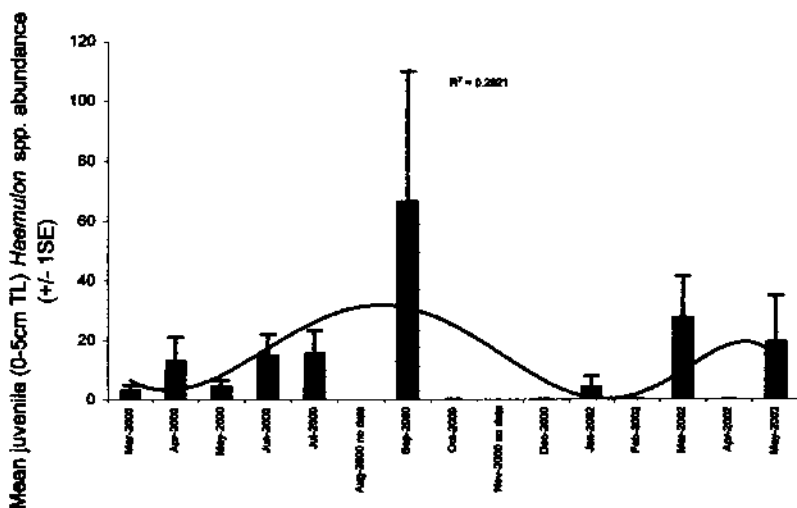


Figure 7. Monthly mean abundance of juvenile (<5cm TL) *Haemulon* spp. on Natural Hardbottom study.

DISCUSSION

Data from the four studies, over several different years, indicated a similar spatial (cross-shelf) and temporal pattern of juvenile *Haemulon* spp. abundance. The study examining fishes on the Natural Hardbottom revealed that juvenile *Haemulon* spp. may show preference for a shallow, nearshore habitat. On reef census sites deeper than approximately 10 m, juveniles were rarely recorded. These findings are consistent with the results of other studies. Linderman and Snyder (1999) found that over 80% of fishes recorded on nearshore hardbottom sites offshore Jupiter, Florida were juveniles. In St. Croix, juvenile French grunts (*H. flavolineatum*) and white grunts (*H. plumieri*) commonly associated with shallow patch reefs with adjacent sea grass beds (Ogden and Ehrlich 1977). It is often postulated that juveniles of a variety of species use shallow water habitats as a nursery (Linderman et al. 2000). Our data for the Natural Hardbottom portion of this study certainly suggest that this may be so, however, data from the Reefball and GS module studies are contradictory. Newly settled and early juveniles were commonly found at 21m depth on artificial reefs modules. Additionally, artificial reef modules deployed at both 7m or 21m depth had a more than an order of magnitude higher density of juvenile (< 5cm TL) *Haemulon* spp. than the nearshore-most hardbottom in Broward County, where juvenile abundance is normally highest (Sherman 2000, Baron and Spieler in review). Why? The obvious answer would appear to be refuge

from predators. Artificial reefs deployed in an area where essentially no natural refuge exists, such as a sand flat, allow fish to live where they normally would not. Because newly settled and early juvenile *Haemulon* spp. are capable of recruiting to and living at these depths, it is difficult to acknowledge the nearshore environment as *essential* fish habitat and provides a cautionary note to the assumption that abundance implies preference (Wilbur 2000). It may be that use of shallow water habitats by *Haemulon* spp. is not obligatory but simply recruitment to the best available habitat.

Gilliam (1999) found significant increases in newly settled and early juvenile *Haemulon* spp. abundance on modules enclosed with caging material that increased refuge from predators, versus uncaged controls. In another study, concrete block was added to the internal void space of Reefballs to create additional refugia. Again, the result was a significant increase in *Haemulon* spp. abundance when compared to the control treatment (no block) (Sherman 2000). Although these studies demonstrate the importance of refugia, the quantity/quality of refuge cannot be the only determinant for cross-shelf distributional patterns of juvenile *Haemulon* spp. Vertical profile and rugosity, topographical attributes thought to create shelter for fishes, are substantially higher on the Offshore and Middle reef tracts in Broward County, Florida (authors' unpub. data). Yet, the results of the Natural Hardbottom study indicate the Inshore reef tract has the highest abundance of juvenile *Haemulon* spp. If refugia are the sole determinant of distribution and refuge is in greater supply on the Offshore and Middle tracts, why are juveniles not regularly present there? We can only speculate. It is possible that predators are less abundant or efficient in the nearshore environment. There is also the possibility that residents (*e.g.*, territorial damselfishes [Pomacentridae]) already residing on the Middle and Offshore tracts competitively exclude juveniles. Differences in food supply and variety may also be responsible for the distributional patterns. Further experimentation is required before the determinant(s) of *Haemulon* spp. distributional patterns are found.

Lighty (1977) noted the presence of at least three relict coral ridges, in sequentially deeper waters, following the coastline of Dade, Broward and Palm Beach Counties; a product of reef development at differing sea-levels. At our current sea-level status, these ridges do not form leeward protected waters (lagoon). Therefore, patch reefs, by definition, are nonexistent and seagrass beds and mangroves are limited to the intracoastal waters leeward of the barrier island. In Curacao, Netherlands Antilles, juveniles of two grunt species (*H. parra* and *H. sciurus*) exhibited dependence for mangroves and seagrass beds (Nagelkerken et al. 2001). In Broward County, seawalls commonly border intracoastal waterways where mangroves once existed. In a study examining the differences in fish assemblages on natural and mitigated mangrove areas in Broward County, no juvenile *Haemulon* spp. were recorded (Roberts 1994 unpub. MS thesis). Although an extensive ichthyofaunal study of seagrass beds in our area has not been performed, data collected from our area suggest the most densely populated natural area of juvenile *Haemulon* spp. exists on the most inshore hardbottom habitat (Baron and Spieler in review). In Barbados, Tupper (1989) also found that juvenile

haemulids often settle onto reefs. Our results do not necessarily contradict the study conducted in Curacao because, in our area, the most abundant juvenile taxa are *H. aurolineatum* and *H. flavolineatum* (Bristol et al. in prep.). In Nagelkerken and coauthors (2001), *H. aurolineatum* was apparently not common enough to warrant analysis and *H. flavolineatum* exhibited only slight dependence to mangroves and seagrass beds. In contrast, to the Curacao study, early juvenile *H. parra* was one of the most abundant taxa found in a study examining nearshore hardbottom sites (Lindeman and Snyder 1999). This finding challenges the results of the Nagelkerken and coauthors (2001) study and implies a facultative rather than obligatory dependence for mangroves and seagrass beds for *H. parra* and probably other species.

While juvenile *Haemulon* spp. were present year-round in three of the four studies (all three used reef modules), summer months had the highest abundances in all studies, evidence of a possible settlement pulse associated with greater reproductive activity during certain months of the year (Munro et al. 1973). In contrast, most reef fishes appear to settle during a particular time of year (Williams and Sale 1981). Even though data from the present study indicate maximum abundance of juvenile *Haemulon* spp. occurs in summer months, it is unknown if this apparent seasonal peak is reflected by a broad time interval of recruitment for all (or most) species or if it is a composite signal of many species-specific uni- or multimodal recruitment peaks. Obviously, this information is critical for effective management.

With the caveat that it is risky to draw conclusions from small differences in length data derived from visual censuses (Sherman et al. 1999), one of the more interesting findings of the present study was the apparent difference in peak abundance between newly settled individuals and early juveniles. Two of the three studies that used artificial reef modules (*i.e.*, Reefball study, and Isolation study) showed the abundance of newly settled individuals increased and peaked a month or two before the abundance of early juveniles peaked (Figures 3 and 6). This lag in the abundance of early juveniles is likely due to a transition corresponding with growth of newly settled individuals. Based on growth curve data for *H. flavolineatum*, a newly settled individual could be promoted to an early juvenile at approximately 45 days after hatching (Brothers and McFarland 1981). Since settlement occurs at approximately 15 days, it would take about one month for a newly settled juvenile to enter the early juvenile stage. This was best shown in the Isolation study (Figure 6). The abundance of newly settled individuals peaked in late spring while early juvenile abundance peaked in the summer. At its peak, early juvenile abundance on the modules, however, more than doubled the peak of newly settled individuals. The logical explanation for this anomaly is emigration from other areas.

In conclusion, the results of this study suggest that, overall, newly settled individual *Haemulon* spp. primarily associate with the nearshore environment, exhibiting highest abundance in late spring/early summer. However, these fishes will settle on artificial reefs in deeper waters at higher densities than the natural

nearshore hardbottom. The determinant(s) for this occurrence are still unknown and it is our intention to examine a variety of post-settlement ecological processes including: predation, competition, and food quality/quantity in future studies. Without knowledge of what drives the cross-shelf patterns of settlement, successful management of haemulids will be guesswork, at best.

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