

# **SPATIAL AND TEMPORAL PATTERNS OF LARVAL FISH DISTRIBUTION IN SURFACE WATERS OF LA PARGUERA, PUERTO RICO: Preliminary report**

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## **ABSTRACT**

This study examined distribution patterns of larval fishes in La Parguera Bay and adjacent oceanic waters in Southwestern Puerto Rico, an area of extensive coral reef development. Larval fishes were sampled at the surface with 202 and 750 : m mesh conical plankton nets at five stations along an inshore-offshore gradient. Stations included a shallow mangrove channel off the shoreline, back-reef and fore-reef areas, the shelf-edge reef and one offshore station located two miles off the shelf-edge. A total of 40 families and, at least, 43 species of larval fishes have been identified. The offshore station had the highest number of species, (19 species), most of which were oceanic types. Relatively higher abundance of pre-flexion larvae was found inshore, at the fore-reef and back-reef stations (means : 45.2 and 40.2 Ind/100m<sup>3</sup>, respectively). Conversely, more post-flexion larvae was found offshore (mean : 6.30 Ind/100m<sup>3</sup>). This trend was influenced by the relatively higher abundance of beloniform taxa (flyingfishes, ballyhoo, needlefishes) offshore, which only hatch as post-flexion larvae. Patchiness, occurring at time scales of shorter duration than the monthly sampling interval, appeared to be the dominant feature of temporal variability in total post-flexion and pre-flexion larval abundance. Peaks of significantly higher abundance were observed during different months at each station. There was a synchronized peak of larval fish abundance at the shelf-edge and offshore stations during August. This patch was multispecific in taxonomic composition (11 families), and included a wide range of ontogenetic stages (pre-flexion and post-flexion) of oceanic, as well as reef associated species. The high relative abundance of oceanic taxa in this patch (Exocotidae, Gempylidae, Macrorhamphosidae, Scombridae, Istiophoridae, Nomeidae) suggests an offshore origin. Co-occurrence of reef associated taxa as well (Hemiramphidae, Pomacentridae, Carangidae, Ostracidae) may be indicative of high larval survival in a physically driven offshore retention zone.

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### INTRODUCTION

Spatial and temporal variability patterns of larval fish distributions and abundance, taxonomic composition and ontogeny are fundamental aspects of coral reef fish recruitment dynamics. Such information is critically important in the design and location of seawater intake structures and thermal effluents associated with power plants and other industrial developments, and with formulation of fisheries management strategies directed to protect overexploited stocks from growth and recruitment overfishing (e. g. Polachek 1989; PDT 1990). The self-recruitment potential versus expatriation dichotomy represents one of the main concerns in evaluation of closed fishing areas as a management option for Caribbean coral reef fisheries. Offshore occurrence of coral reef fish larvae in the very few samplings performed in the Caribbean (Richards 1984; Smith et al. 1987) tend to support the generalized theory that reef fishes with planktonic eggs have offshore larval distributions (Leis and Miller 1976; Young et al. 1986). Yet, insular shelf regions with substantial coral reef development in the Caribbean have not been examined, and the relatively low abundance of coral reef fish larvae found in offshore samplings calls for a more comprehensive search for inshore larval distributions and oceanographical processes affecting them.

This study aims to provide a baseline description of temporal and spatial variability of larval fish abundance, taxonomic composition and ontogenic distributions along an inshore-offshore gradient in surface waters of La Parguera Bay and adjacent offshore waters.

### Background and Literature Review

Most coral reef fishes reproduce from demersal or planktonic eggs which develop into a planktonic/pelagic larval stage. Duration of the planktonic stage (egg and larvae) varies considerably among species (Brothers et al., 1983; Victor, 1986), as well as the morphological and physiological adaptations of larvae for planktonic life (Smith et al., 1987). Dispersal mechanisms seem to operate at different temporal and spatial scales for different species due to an interplay of factors, such as the duration of planktonic stage, larval morphology and behavior, adult reproductive modes and spawning strategies, and water column hydrography (Richards, 1984, Williams et al., 1984; Shapiro et al., 1988; Williams & English, 1992; Cowen, in press). Consequently, marked inshore-offshore and vertical gradients in taxonomic composition of reef fish larvae have been noted (Leis & Miller, 1976; Leis, 1982; Young et al., 1986; Yoklavich et al., 1992). Leis & Miller (1976) found that most hawaiian coral reef fishes with planktonic eggs had offshore larval distributions, while those with non-

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planktonic (demersal or attached) eggs were most commonly found inshore. Similar findings were reported by Young et al., (1986) from cross-shelf transects off Western Australia. Offshore larval distributions of inshore reef fishes had been previously reported for the eastern tropical Pacific (Ahlstrom, 1971, 1972). At present very limited information is available on spatial and temporal variability patterns of abundance and taxonomic distribution of Caribbean coral reef fish larvae. Such information is key to basic understanding of recruitment dynamics and early fish life histories and precludes formulation of management strategies for coral reef associated fisheries, such as the establishment of closed fishing areas.

Richards (1984) reported distribution patterns of reef fishes offshore throughout the Caribbean and the southern Gulf of Mexico, but insular shelf zones, and particularly coral reef areas, were in most part excluded from the (MARMAP) sampling scheme. A total of 50 families of inshore fishes were represented offshore in the MARMAP study (Richards 1984), their combined abundance, however, accounted for less than 30 % of the total individuals collected. Inshore reef fish families, such as Scarids, Gobiids, Bothids, and Labrids combined for approximately 15 % of the total collection. No other family of inshore reef fishes represented more than 1 % of the total collection. Offshore, mesopelagic taxa, such as Scopeliformes, Myctophids, and Gonostomatids accounted for more than 75 % of the total MARMAP bongo net collection. Exocoetids, Mullids, Myctophids and Mugilids were the most abundant families of ichthyoplankton represented in MARMAP neuston samples (Richards 1984). Both mugilids and mullids, along with a few other inshore reef fish families were abundant in offshore neuston collections. Nevertheless, the lack of synoptic samplings inshore precludes any conclusive analysis of distribution patterns of Caribbean coral reef fish larvae from this study.

In a preliminary evaluation of inshore and offshore size distributions of Caribbean larval fishes, Smith et al. (1987) noted the presence of a 'near field assemblage', or a group of inshore reef fishes that spend their entire life cycle in the vicinity of Caribbean reefs. Based mostly on the taxonomic distribution of their night-light collections, Smith et al. (1987) suggested that such inshore larval fish assemblage is comprised by only a small number of families. This implies, or raises the hypothesis, that the community structure of Caribbean coral reef fishes is mostly dependant upon recruitment by offshore transported larvae (the far-field assemblage). In such case, an increase of spawning stock biomass in any given coral reef, mediated by closure management strategies (e.g. marine fishery reserves) would have limited influence on a regional basis, unless offshore larval retention areas and/or return mechanisms to natal and/or adjacent

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reefs would be operant. Dennis et al. (1991) reported 24 families of larval fishes from night collections in mangrove, seagrass, and inshore coral reef habitats in La Parguera. At present a comprehensive evaluation of inshore larval fish distribution in Caribbean coral reef environments have not been performed.

The generalized theory that spawning strategies of most coral reef fishes are adapted to facilitate offshore transport of eggs and larvae (Sale 1970; Emery 1972; Johannes 1978) is poorly substantiated by physical oceanographic data (Shapiro et al. 1988; Leis 1991). Tidal currents have been identified as mechanisms for egg dispersal away from reefs in the Indo-Pacific (Johannes 1978; Robertson 1983; Thresher 1979; Bell and Colin 1986), although net offshore transport has not been demonstrated (Leis 1991). Recent investigations in La Parguera (Shapiro et al. 1988; Appeldoorn et al. 1994; Hensley et al. 1994), have tested the hypothesis that pelagically-spawning coral reef fishes select sites and times for spawning that result in eggs being rapidly transported away from reef areas. This study was conducted at San Cristobal, a small inshore reef in La Parguera, using the bluehead wrasse, *Thalassoma bifasciatum* as a model species. Transport mechanisms (e.g. currents) away from reef sites were greater at non-spawning times than at spawning times, while no significant differences in transport resulted between spawning and non-spawning sites. These results do not support the hypothesis that spawning behavior favors transport of eggs away from reef areas. Little net offshore transport of eggs was observed, due to nighttime current reversals associated with drop in wind stress. Indeed, net on-shelf water movement along the bottom during this time was opposite to that observed on the surface (Tyler 1992). These indicate the existence of physically driven mechanisms potentially capable of retaining eggs and larvae inshore. Hatching of *Thalassoma* eggs spawned a San Cristobal was inferred to occur inshore (Appeldoorn et al. 1994; Hensley et al. 1994).

Colin & Clavijo (1988) observed 26 coral reef fish species spawning at the shelf-edge off La Parguera, Puerto Rico, including several commercially important families, none of which showed spawning activity associated with tidal phase or currents. More than an offshore transport mechanism, Colin & Clavijo (1988) suggested the changing tide as a possible signal for group spawning at a topographically distinct site within the insular shelf. The vast majority of Caribbean reefs are not affected by pronounced tidal currents comparable to those in the Indo-Pacific, and while offshore larval occurrence of inshore reef fish populations has been noted (Garc'a and Ram'rez, in preparation), transport mechanisms have not been identified. Drifter trajectories monitored at the shel-edge on four different experiments between October and December (Kioroglou 1992) revealed westward flows in 30 October and 4

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December, northwest flows on 11 December, and northeast (reversed) flows during 23 October. These preliminary observations do not support offshore transport of shelf-edge spawned eggs. Evidently, much more observations are needed to characterize surface current patterns at the shelf-edge and assess the the fate of eggs trajectories spawned at this inshore-offshore boundary.

The persistence of local fish populations in isolated island reefs in the Western Central Atlantic has led investigators to examine the self-recruitment potential and hydrographic processes operating at these sites. Schultz and Cowen (1993) compared the duration of larval planktonic stage (PLD's) of reef fishes in Bermuda with estimates of time required for transport of larvae from other potential reef sites. They concluded that the ichthyofaunal community in Bermuda is mainly replenished via a pool of locally spawned larvae and retained in the vicinity of the atoll. Topographically (reef) induced eddy systems have been proposed as oceanographic features which could restrict dispersal and enhance larval return from offshore areas (Sale 1970; Emery 1972; Johannes 1978). Lobel and Robinson (1986) proposed that a cold-core eddy in the vicinity of the island of Hawaii caused entrainment and retention of larval fishes near their natal reefs. Unfortunately, relatively few fish larvae were collected to substantiate their argument. Williams et al. (1984) and Williams & English (1992) argued that the reef associated eddies in the Great Barrier Reef (GBR) occur, but do not act as larval retention areas, nor represent mechanisms of larval return to natal reefs because of their high instability in relation to the duration of ichthyoplanktonic stages. In turn, Williams & English (1992) advocated in favor of mesoscale patches of multispecific taxa of larvae reaching the reef as an important process influencing larval recruitment to Myrmidon Reef, (GBR) Australia. In the Caribbean, topographically steered flows, other than eddies, have been proposed as potential return mechanisms for offshore distributed larvae of coral reef fishes spawned locally in the vicinity of the island of Barbados (Cowen, in press).

Available information on the reproductive behavior of Caribbean reef fishes is indicative of peak spawning during winter months, high seasonal variability between populations, continuous reproduction, and extended seasonality within populations (Munro et al. 1973; Erdman 1977; Colin 1982; Colin et al. 1987; Colin and Clavijo 1988). This suggests that highly variable oceanographic conditions might prevail at the time of spawning of any given population. Yet, our present understanding of temporal and spatial distributions of coral reef fish eggs and larvae is very limited, and the relatively scarce information available on fish spawning times, sites locations and oceanographic

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conditions operating at those times and sites make predictions about the fate of eggs and larvae highly uncertain.

### **METHODS**

Larval fishes were sampled at five stations along an inshore-offshore transect in surface waters of La Parguera. Stations were established at a shallow mangrove channel off the shoreline, at the backreef lagoon of Enrique Reef, at the fore reef platform of Turrumote, Media Luna and Laurel Reefs, at the shelf-edge, and at an offshore station located two miles off the shelf-edge, due south off Turrumote Reef (Fig 1). Triplicate surface samplings were taken at each station with a 0.5 m ring 202 : m mesh plankton net fitted with a calibrated flowmeter. In addition, one long (10 minutes) surface sweep using a 750 : m mesh plankton net was taken at each station. All samples were preserved in a 5% formalin and seawater solution. Surface water temperature, salinity and Secchi disk measurements were taken at each station. A total of 24 biweekly samplings were performed. Samples were collected from January through December, 1993.

Taxonomic identifications were made using the following references: Moser et al. (1984), Matarese et al. (1989), Leis and Trnski (1989), Leis and Rennis (1983), Randall (1968), Jones et al. (1978) and a set of drawings and meristics from larval fishes from the Central Atlantic (Richards, unpublished). Larval fishes were sorted and classified as pre-flexion or post-flexion larvae, based on the upward flexion of the urostyle, which precedes formation of the caudal fin. All flexion and post-flexion as well as identifiable pre-flexion larvae (at least to family level) were measured ( $\pm 0.1\text{mm}$ ). Unidentifiable pre-flexion were counted and included in the total larval abundance estimates of each sample. Enumerations, identifications and measurements of fish larvae were done under dissecting microscopes. Entire samples were sorted and processed for identifications and measurements of pre-flexion and post-flexion larvae. A reference (voucher) collection of larval fishes was prepared, along with a description of meristics, pigmentation patterns and other relevant taxonomic information for each voucher. Ontogenetic series of larval fishes were prepared in an effort to reach taxonomic clues leading to identification of early developmental stages, and to allow future taxonomic and systematic descriptions of poorly known species. At present, 60 ichthyoplankton samples have been processed for identification to the lowest possible taxon.

A preliminary analysis of spatial and temporal variability patterns of fish larval abundance was prepared from the first 12 monthly samplings. A total of 180 samples (triplicates from 5 stations during 12 months) were included in this preliminary analysis. Spatial and temporal patterns of pre-flexion and post-

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flexion larval abundance were tested with a two-way ANOVA with replication (Sokal & Rolf, 1969). Preliminary inspection of the data revealed that variances were positively correlated with means. A natural logarithm transformation was applied to equalize variances and normalize distributions of abundance data (Ind/10 m<sup>3</sup>).

Variance homogeneity was tested with an F-max test. Temporal and spatial effects were calculated for each station and each month whenever interaction factors in two-way ANOVA's were significant.

Deviations from expected values were calculated from:

$$\text{Month/station effect} = \text{observed} - \text{month/station means} \quad (1)$$

$$\text{Expected mean} = \text{stat effect} + \text{month effect} \quad (2)$$

$$\text{Deviation} = \text{observed} - \text{expected} \quad (3)$$

### **RESULTS AND DISCUSSION**

Larval Fish Taxonomic Composition and Spatial/Temporal Abundance Patterns:

Larval fishes from 40 families and at least 43 species have been identified so far, in the limited number of samples processed for identification to the lowest practicable taxon. Distribution of these taxa by sampling station is shown in Table 1. The offshore station had the highest number of species with 20, including eight only collected at this station (6 oceanic and 2 reef species). A total of 491 larvae were collected at the offshore station. Post-flexion larvae represented 23.0 % of total larvae offshore. Inshore stations accumulated 36 species distributed in 30 families from a total collection of 3,049 larvae. Shelf-edge, fore-reef and mangrove stations were represented by 11, 12 and 10 fish families respectively.

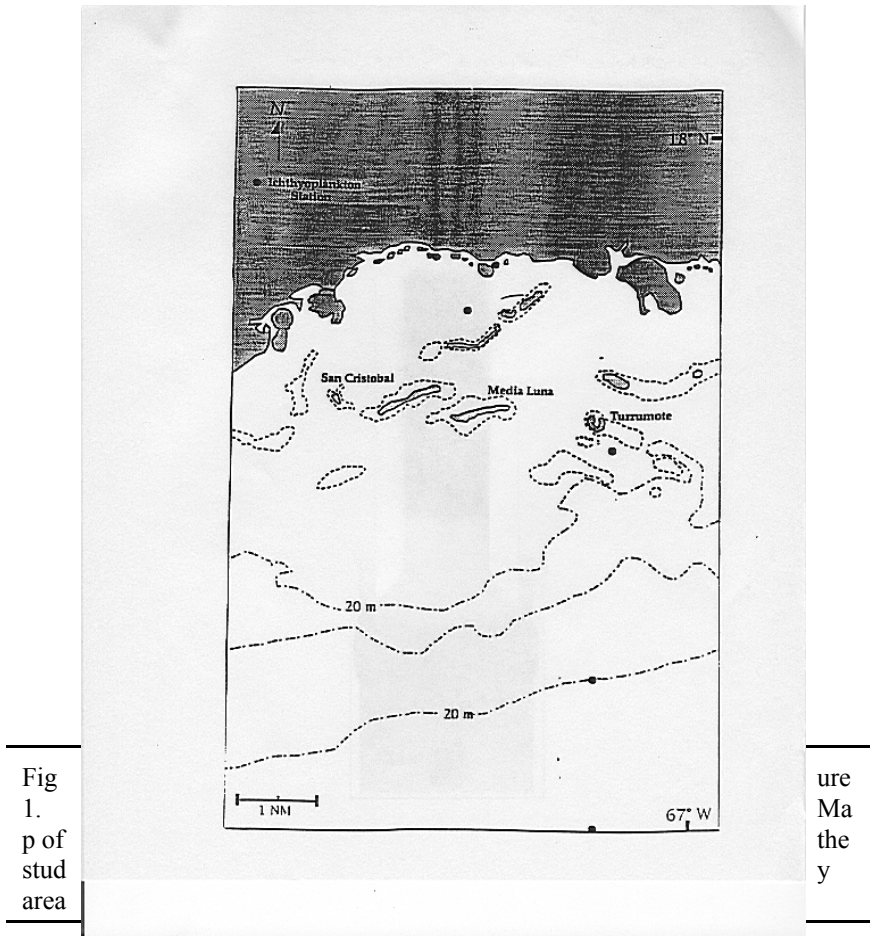


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Only six families have been identified from the backreef station. Pre-flexion stages represented more than 95 % of total larvae collected at inshore stations, except at the shelf-edge, where post-flexion larvae were 18.1 % of the total. The highest numbers of post-flexion larvae were collected at the shelf-edge station (160), and the highest number of total larvae were collected at the fore-reef station (939).



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Results of the two-way ANOVA procedure testing temporal, spatial, and interactions effects (months x stations) in both pre-flexion and post-flexion larval abundance data are shown in Table 2.

Significant differences ( $p < 0.001$ ) between stations (spatial effect) and between months (temporal effect) resulted for post-flexion and pre-flexion larvae. In both cases, interaction effects were significant ( $p < 0.001$ ), implying that spatial differences depend upon dates, and viceversa.

### Temporal Patterns:

Monthly variations of total pre-flexion larval abundance at sampling stations in La Parguera are shown in Figure 2. Significant differences in monthly abundance were observed at all stations (Fisher PLSD test;  $p < 0.05$ ). Differences were mostly expressed as ephemeral abundance peaks lacking any consistent seasonal pattern of longer duration than the temporal sampling scale (e. g. one month). In general, peaks of abundance were observed during different months at each stations. For example, an isolated peak of significantly higher abundance was observed at the offshore station in August (mean : 9.6 Ind/10m<sup>3</sup>; Fig 2 a). At the shelf-edge, higher abundance of pre-flexion occurred in December (mean : 23.7 Ind/ 10m<sup>3</sup> ; Fig 2 b). There were two ephemeral peaks of abundance at the fore-reef station (Fig 2 c), one in February (mean : 22.4 Ind/10m<sup>3</sup>) and another during November (mean : 11.1 Ind/10m<sup>3</sup>). Monthly abundances at the back-reef showed significantly higher values in February (mean : 7.0 Ind/10m<sup>3</sup>) and December (means : 6.2 Ind/10m<sup>3</sup>), and a two-month period of higher abundance (relative to 6 other months at that station) during August and September (means: 6.5 and 8.0 Ind/10m<sup>3</sup>, respectively, Fig 2 d). A sustained increase of pre-flexion larval abundance was observed at the mangrove station from September (mean ; 2.6 Ind/10m<sup>3</sup>) to November (mean : 12.8 Ind/10m<sup>3</sup>, Fig 2 e).

The taxonomic composition of pre-flexion larvae at the offshore station in August was characterized by a multispecific assemblage of pelagic (oceanic) and coral reef species that included a total of 11 families (e.g. Istiosphoridae, Scombridae, Nomeidae, Macroramphosidae, Gempylidae, Hemiramphidae, Pomacentridae, Mullidae, Carangidae, and Ostracidae). Taxonomic structure of pre-flexion larvae in shelf and nearby offshore waters of La Parguera is under examination, but incomplete at this point, and will be reported later.

Monthly variations in abundance of total post-flexion larvae at each of the five sampling stations along the inshore-offshore transect are shown in Figure 3. Offshore and shelf-edge stations displayed an ephemeral, but synchronized peak of significantly higher larval abundance in August (Fisher PLSD test;  $p < 0.05$ ; Fig. 3 a-b). Mean abundance in August was more than 6 fold higher than the annual mean abundance at both stations, and coincided with peak abundance of pre-flexion larvae at the offshore station in August. Beloniform larvae (e.g. Exocotidae, Hemiramphidae) were highly abundant among the post-flexion larvae collected at the shelf-edge and offshore stations in August. Monthly variations of post-flexion larvae at the fore-reef station

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revealed a trend of higher abundance between February and April (Fig. 3 c). Ephemeral peaks of abundance were observed at the back-reef station in March and November (Fig 3 d ). Post-flexion larvae were found in very low abundance at the mangrove station, without any significant variation in abundance between months (Fig 3 e).

Patchiness, occurring at time scales of shorter duration than the monthly sampling interval, appeared to be the dominant feature of temporal variability in total post-flexion and pre-flexion larval abundance in La Parguera shelf and nearby offshore waters. Otherwise, there was a mostly uniform abundance of fish larvae at each station throughout the year. Taxonomic identification of ichthyoplankton samples is still in progress, and it is not possible at present to determine if seasonality was occurring at the level of populations.

Also, inferences about oceanographical processes potentially relevant to patch formation and dynamics await additional taxonomic information from available samples. Upon examination of the August patch, however, some interesting features have emerged. First, the synchronous manifestation of the patch at two adjacent stations suggest that patch dimension was at least 3 Kilometers wide. It could have been larger than that, but since it was detected at the end of the gradient, its offshore range went undefined. Second, the multispecific nature and heterogeneous age structure of the fish assemblage suggest that the patch was physically driven, not associated to any particular cohort.

Third, the high numerical abundance of oceanic taxa (billfish, flyingfish, tuna etc) is an indication that the patch had an offshore trajectory. Further evidence of the offshore origin of this patch is the fact that flying fish were the numerically dominant assemblage. Flying fish eggs are attached to pelagic Sargassum spp. clusters concentrated by surface oceanic currents that travel westerly along the South coast of Puerto Rico. It is possible that these currents represent zones of higher productivity (perhaps associated with Sargassum ) and to some extent allow for enhanced survival rates of ichthyoplankton.

### **Spatial Differences**

Spatial differences in abundance of pre-flexion larvae were significant in six out of the 12 sampling dates. (One-way ANOVA; Table 3). Fore-reef and back-reef stations had the higher mean abundance of pre-flexion larvae (study means : 4.52 and 4.02 Ind/10m<sup>3</sup>, respectively).

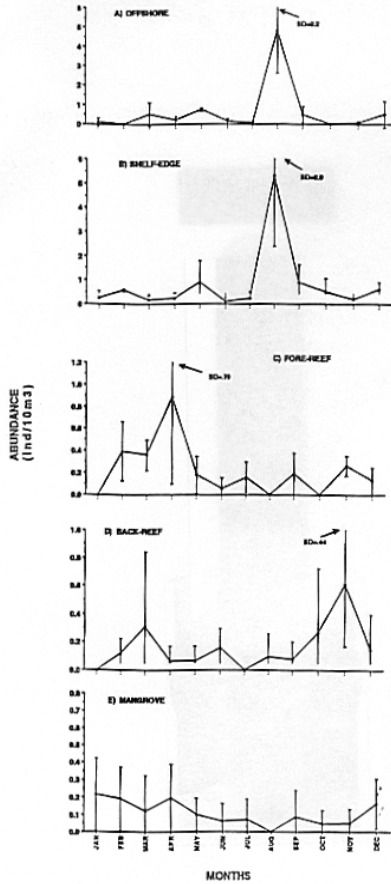


Figure 2. Monthly variations of total pre-flexion larval abundance at sampling stations in La Parguera

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Figure 3. Monthly variations in abundance of total post-flexion larvae at each of the five sampling stations along the inshore-offshore transect

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The lowest abundance was at the offshore station (study mean : 1.98 Ind/10m<sup>3</sup>). A large component of spatial variability was associated with isolated peaks of high abundance at different stations each month (e.g. interaction effect). Deviations of observed from expected abundance of pre-flexion larvae, based on the population mean ( : ) plus the corresponding month and station effects are presented in Table 4. The offshore station had lower values than expected in 10 out of 12 sampling dates. It had higher abundance than expected only during

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August (when the patch was detected), and to a minor extent in December, when it was close to the expected value. In contrast, the fore-reef and back-reef combined for a total of nine months of higher than expected. Abundance at the shelf-edge was much higher than expected in December, and again during February. Otherwise, abundance was either very close, or below, expected values. Further taxonomic examination of these surface pre-flexion samples, plus additional information from stratified (vertical) sampling needs to be attained in order to provide a basic assessment of the nursery role of inshore and offshore waters for Caribbean reef associated fishes.

Spatial differences in abundance of post-flexion larval fishes were statistically significant in four out of 12 months of sampling (One-way ANOVA ;  $p < 0.05$ ; see Table 5). Differences should be analyzed with caution due to small sample size (e.g. total 491 larvae). Within station variability was generally high due to many replicate samplings where no post-larvae were collected. Shelf-edge and offshore stations had a relatively higher mean abundance of post-flexion larvae (study means : 6.3 and 8.3 Ind/100m<sup>3</sup>, respectively) than inshore stations (range of study means : 1.1-2.2 Ind/100m<sup>3</sup>). Observed abundance was higher than expected in 10 out of 12 months at the shelf-edge, and 6 out of 12 months offshore (Table 6). Other three inshore stations combined for only 4 months in which observed abundance was higher than expected. Back-reef and mangrove stations had one month each, whereas the fore-reef had two months of higher abundance than expected.

The inverted pattern of higher abundance of pre-flexion larvae inshore and higher abundance of post-flexion larvae in surface offshore waters is an interesting result that will require a more in depth taxonomic analysis of the available samples to be interpreted. Higher abundance of post-flexion larvae at offshore and shelf-edge stations was strongly influenced by beloniform taxa throughout the year (e.g. flying fishes-Exocotidae, half-beaks-Hemiramphidae, needle fish-Belonidae). This group is composed of specialized surface dwellers and their larvae hatch from eggs attached to floating objects. Thus, its high relative abundance at the surface would be expected where currents aggregate floating materials. Pelagic Sargassum appears to be one of the principal substrates of attachment for flying fish and other beloniform eggs. Sargassum is concentrated in currents which travel in a northwesterly direction, reaching down to the shelf-edge, but seldom penetrating inshore. Beloniform taxa hatch as post-flexion (flexion takes place inside the egg), which might help explain the lower ratio pre-flexion to post-flexion larvae in surface waters at the shelf-edge and offshore stations. Our limited sampling at the surface may overestimate the relative abundance of beloniformes with respect to other taxa present throughout the water column at any given station. Therefore, vertically integrated sampling will be required to address taxonomic differences between inshore and offshore stations comprehensively.

In terms of taxonomic composition, both oceanic and neritic (reef and estuarine) species have been found at the shelf-edge and offshore stations, whereas only neritic species have been found inshore. Neritic species found at

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the shelf-edge and offshore stations have also been found inshore, except for representatives of the Holocentridae (Squirrelfishes) and Scaridae (Parrotfishes) families. Larval stages of some of the most abundant fish families surveyed at the reefs during visual surveys (Garc'a, unpublished data) (e.g. Lutjanidae, Haemulidae) have not been identified from our collections yet, and appear to be in very low abundance, if at all present, in surface waters sampled. Carangids (Jacks) appear to be distributed at the surface throughout the inshore-offshore gradient.

### PRELIMINARY CONCLUSION:

1. Larval fish distributions were characterized by an almost uniform abundance of total pre-flexion and post-flexion larvae at each station. The occurrence of a multispecific patch at the shelf-edge and offshore stations during August 093, was the most prominent feature of ichthyoplankton temporal variability. The patch included a wide range of ontogenic stages (pre-flexion and post-flexion) of oceanic, as well as reef associated species, suggesting that patch formation was physically driven.

2. The high relative abundance of exocoetid taxa (flying fishes, ballyhoo, etc.) suggest that these patches have an offshore origin. Floating Sargassum mats serve as egg attachment sites for oceanic flying fishes (Exocotidae) and may represent an 'oasis in the middle of a dessert' for a wide array of fish larval taxa.

3. Spatial differences in larval fish distributions were highlighted by relatively higher pre-flexion and relatively lower post-flexion larvae inshore. This trend may be influenced by the relatively higher abundance of beloniform taxa offshore which only hatch as post-flexion larvae. The offshore station had the highest number of species, most of which were oceanic types. Only two larval taxa collected offshore has not been collected inshore. A more comprehensive taxonomic analysis is needed to make further inferences about the nursery role of reef dominated shelf areas for larval fishes.

4. The most intriguing result of the larval fish study was the absence of lutjanids (snappers) and haemulids (grunts) from our plankton collections. These two groups were among the numerically dominant populations in reef surveys, and are of primordial importance to Caribbean artisanal fisheries. Therefore, the effectiveness of a Marine Fishery Reserve (MFR) as a management option will be strongly influenced by the larval recruitment patterns of these two taxa. Stratified samplings and other methodological strategies have been proposed to investigate this subject.

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Table 1. Preliminary list of ichthyoplankton taxa in shelf and nearby oceanic waters of La Parguera, Southwest Coast of Puerto Rico.

GRADIENT STATIONS					
TAXON	OFFS HORE	SHELF-EDGE	FORE-REEF	BECK-REFF	MANGROVE
ALBULIDAE <i>Albula bulpes</i>					X X
CLUPEIDAE		X	X		
SYNODONTIDAE					X

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MYCTOPHIAE		X			X
ANTENNARIIDAE		X			
BELONIDAE Strongylura sp.	X X	X	X		
HEMIRAMPHIDAE Hemirhamphus sp.	X X	X X	X		
EXOCOTIDAE Cypselurus sp.	X	X X			
HOLOCENTRIDAE	X				
MACRORHAMPHOSIDAE <i>Macrorhamphosus scolopax</i>	X X				X
SYNGNATHIDAE	X				X
DACTILOPTERIDA E <i>Dactilopterus volitans</i>	X X				
SERRANIDAE		X			
CARANGIDAE <i>Caranx bartholomaei</i> <i>Carangoides ruber</i> <i>Trachinotus falcatus</i> <i>Oligoplites saurus</i>	X X X	X X	X X	X X X	X  X X
CORYPHAENIDAE <i>Coryphaena hippurus</i>	X X				
GERRIDAE Eucinostomus sp.	X	X	X		X X
SCIANIDAE		X			
MULLIDAE	X				X
EPHIPPIDAE Chaetodipterus sp.					X X

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POMACENTRIDAE TYPE 1 TYPE 2 TYPE 3 TYPE 4	X  X X	   X	    	    X	    X X
MUGILIDAE <i>Mugil curema</i>	X	X	 X	   	   X
SPHYRAENIDAE <i>Sphyraena picudilla</i> <i>Sphyraena barracuda</i>	X X	X X	X  	   	X X
POLYNEMIDAE Polydactylus sp.	  	  	  	  	X X
LABRIDAE TYPE 1 TYPE 2	  	  	  	X X X	  
SCARIDAE	X	  	  	  	  
TRIPTERYGIIDAE	  	  	X	  	  
BLENNIIDAE	  	  	  	  	X
GOBIDAE	  	  	X	  	X
MICRODESMIDAE	  	  	X	  	  
ACANTHURIDAE	  	  	X	  	  
GEMPYLIDAE	X	X	  	  	  
SCOMBRIDAE Thunnus sp	X	X	X X	  	  
XIPHIIDAE <i>Xiphias gladius</i>	X X	  	  	  	  
ISTIOPHORIDAE	X	  	  	  	  
NOMEIDAE	X	X	  	  	  
ACHIRIDAE <i>Achiurus lineatus</i>	  	  	  	  	X X
OSTRACIDAE	  	  	X	  	  

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TETRAODONTIDAE Sphaeroides sp.			X X	X	
DIODONTIDAE		X			
TOTAL FAMILIES	20	17	15	6	16

Table 2. Two-way ANOVA testing spatial/temporal patterns of pre-flexion and post-flexion larval abundance.

A) Pre-flexion

Source	df.	Sum squares	Mean squares	F-test	P value
dates (A)	11	14	1.27	3.84	.0001
stations (B)	4	6.7	1.68	5.05	.0009
AB	44	48.94	1.11	3.35	.0001
Error	120	39.81	0.33		

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B) Post-flexion

Source	df:	Sum squares	Mean squares	F-test	P value
dates (A)	11	4.59	.42	10.41	.0001
stations (B)	4	2.96	.74	18.47	.0001
AB	44	11.12	.25	6.31	.0001
Error	120	4.8	.04		

Table 3. Monthly mean abundances of pre-flexion along inshore-offshore gradient in La Parguera shelf and nearby offshore waters.

STATIONS								
Months	off shore	shelf edge	fore reef	back reef	mangrove	mean	month effect	1-way ANOVA p-value
JAN	2.51	1.36	4.61	2.88	2.43	2.76	0.73	0.64
FEB	0.35	3.94	22.4	6.99	0.52	6.84	-3.35	0.11
MAR	2.09	2.16	4.15	2.97	1.50	2.57	0.92	0.77
APR	0.10	0.90	1.43	3.38	1.17	1.40	2.09	.005*

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MAY	2.08	4.36	0.76	2.07	1.90	2.23	1.26	0.09
JUN	1.44	2.39	1.63	2.36	0.40	1.64	1.85	0.30
JUL	0.94	0.33	2.03	1.68	0.34	1.06	2.43	0.09
AUG	9.63	1.86	1.59	6.53	1.76	4.27	-0.78	.022*
SEP	0.93	0.77	0.26	8.03	2.63	2.52	0.97	.001*
OCT	1.30	4.30	3.29	1.95	6.65	3.50	-0.01	.043*
NOV	0.41	1.51	11.0	3.32	12.83	5.83	-2.34	.011*
DEC	1.99	23.6	1.01	6.15	3.25	7.21	-3.72	.004*
MEAN	1.98	3.96	4.52	4.02	2.95	$\mu=$ 3.49		
Sta/eff	1.51	- 0.47	- 1.03	- 0.54	0.54			

Table 4. Deviation from expected monthly mean abundances of pre-flexion fish larvae.

STATIONS					
Months	off shore	shelf edge	fore reef	back reef	mangrove
JAN	-3.22	-2.39	1.42	-0.80	2.33
FEB	-1.30	4.27	23.29	7.40	-0.16
MAR	-3.83	-1.78	0.77	-0.90	-3.45
APR	-6.99	-4.21	-3.12	-1.66	-4.95

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MAY	-4.18	0.08	-2.96	-2.14	-3.39
JUN	-5.41	-2.48	-2.68	-2.45	-5.48
JUL	-6.49	-5.12	-2.86	-3.70	-6.12
AUG	5.41	-0.38	-0.09	4.36	-3.05
SEP	-5.04	-3.22	-3.17	-4.11	-2.37
OCT	-3.69	1.29	0.84	-0.99	2.63
NOV	-2.26	0.83	10.95	2.71	11.14
DEC	0.71	24.36	2.27	6.92	2.94

Table5. Monthly mean abundances of post-flexion along inshore-offshore gradient in La Parguera shelf and nearby offshore waters.

STATIONS								
Months	off shore	shelf edge	fore reef	back reef	mangrove	mean	month effect	1-way ANOVA p-value
JAN	0.12	0.26	0.00	0.00	0.22	0.12	0.27	.319
FEB	0.00	0.58	0.39	0.12	0.19	0.26	0.13	.006*
MAR	0.50	0.17	0.36	0.31	0.12	0.29	0.10	.763
APR	0.21	0.23	0.89	0.06	0.19	0.32	0.07	.059
MAY	0.74	0.88	0.18	0.06	0.10	0.39	0.00	.036*

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JUN	0.14	0.08	0.06	0.16	0.06	0.10	0.29	.798
JUL	0.06	0.24	0.16	0.00	0.07	0.10	0.29	.396
AUG	4.80	5.31	0.00	0.09	0.00	2.04	-1.65	.000*
SEP	0.49	0.90	0.19	0.07	0.09	0.35	0.04	.074
OCT	0.00	0.50	0.00	0.27	0.05	0.16	0.23	.268
NOV	0.05	0.18	0.26	0.61	0.05	0.23	0.16	.020*
DEC	0.50	0.62	0.13	0.15	0.16	0.31	0.08	.306
MEAN	0.63	0.83	0.22	0.16	0.11	$\mu=$ 0.39		
Sta/eff	- 0.24	- 0.44	0.17	0.23	0.28			

Table 6. Deviation from expected monthly mean abundances of post-flexion fish larvae.

STATIONS					
Months	off shore	shelf edge	fore reef	back reef	mangrove
JAN	-0.31	0.04	-0.83	-0.89	-0.72
FEB	-0.28	0.50	-0.30	-0.63	-0.61
MAR	0.25	0.12	-0.30	-0.41	-0.65
APR	-0.01	0.21	0.26	-0.63	-0.55
MAY	0.59	0.93	-0.38	-0.56	-0.57
JUN	-0.30	-0.16	-0.79	-0.75	-0.90



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JUL	-0.38	-0.003	-0.69	-0.91	-0.89
AUG	6.30	7.01	1.09	1.12	0.98
SEP	0.30	0.91	-0.41	-0.59	-0.62
OCT	-0.38	0.32	-0.79	-0.59	-0.86
NOV	0.26	0.07	-0.46	-0.17	-0.78
DEC	0.27	0.59	-0.51	-0.56	-0.59