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Ichthyoplankton Assemblages Sampled by Night Lighting in Nearshore Habitats of Southwestern Puerto Rico

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ABSTRACT

Larval fishes were sampled in four nearshore habitats: coral reef, seagrass bed, mangrove lagoon, and mangrove prop roots in southwestern Puerto Rico. A lift net with attached night light was employed to determine seasonal abundance and species composition of the nearshore ichthyoplankton assemblage. Coral reef and seagrass bed habitats usually possessed the greatest abundance and species richness of larval fishes. Few early stages of larval fishes were collected in mangrove habitats suggesting that they were not nursery areas. The abundance of larval fishes in the open water area of the lagoon was not significantly different from the prop root habitat. Although all habitats were within close proximity (ca. 2 km), there were different patterns in abundance between the coral reef/seagrass bed and mangrove habitats. Based on low abundance of larval fishes and few species captured, the mangroves cannot be considered an important spawning or nursery area for larval fishes in southwestern Puerto Rico.

Introduction

Larval fishes in nearshore tropical environments have not been thoroughly studied because of the difficulty in using standard ichthyoplankton sampling gear in these areas. A major problem encountered when sampling tropical nearshore waters with an active gear, such as a towed net, is navigation among shallow reef areas. Sampling at night amplifies navigational problems, but may be particularly important in nearshore areas where larval fishes may aggregate near bottom or visually avoid towed nets during the day (Powles 1977; Thayer et al. 1983). Thus, most tropical ichthyoplankton studies have been concentrated in oceanic waters where large vessels can operate (Ahlstrom 1971, 1972; Powles 1975; Leis and Miller 1976; Richards 1984). Few studies have examined ichthyoplankton around mangroves (Wyatt 1982; Flores-Coto et al. 1983; Collins and Finucane 1984; Little et al. 1988; Powell et al. 1989) even though these areas are considered major fish nurseries (Heald and Odum 1970).

This study addresses the hypothesis that mangrove areas are spawning or larval nursery areas for fishes in southwestern Puerto Rico. We employed a lift net with attached night light to reduce the problem of sampling with towed nets in coral reef and mangrove habitats.

Materials and Methods

Sampling Area

The study area was located on the southwestern coast of Puerto Rico, the most easterly large island in the Greater Antilles (Fig. 1). The coast is fringed by relatively undisturbed red mangrove forests (*Rhizophora mangle*) and nearshore waters are dotted with red mangrove cays. Many well-developed coral reefs are also found in the area. This portion of Puerto Rico has a dry climate with a total rainfall of 695 mm for 1988. There are no rivers and little freshwater runoff; hence water quality is good. Larval fishes were sampled in four nearshore habitats: mangrove prop root, mangrove lagoon, seagrass bed, and coral reef.

The mangrove prop root habitat included the prop root system adjacent mangrove produced muddy bottom areas (Dennis, in press). Soft mud bottom abutted the mangroves and average water depth for prop-root stations averaged 1.2 m. Four sampling stations were selected here.

A small lagoon surrounded by red mangroves served as the mangrove lagoon habitat and was the primary mangrove habitat sampling site (Fig. 1). The lagoon station

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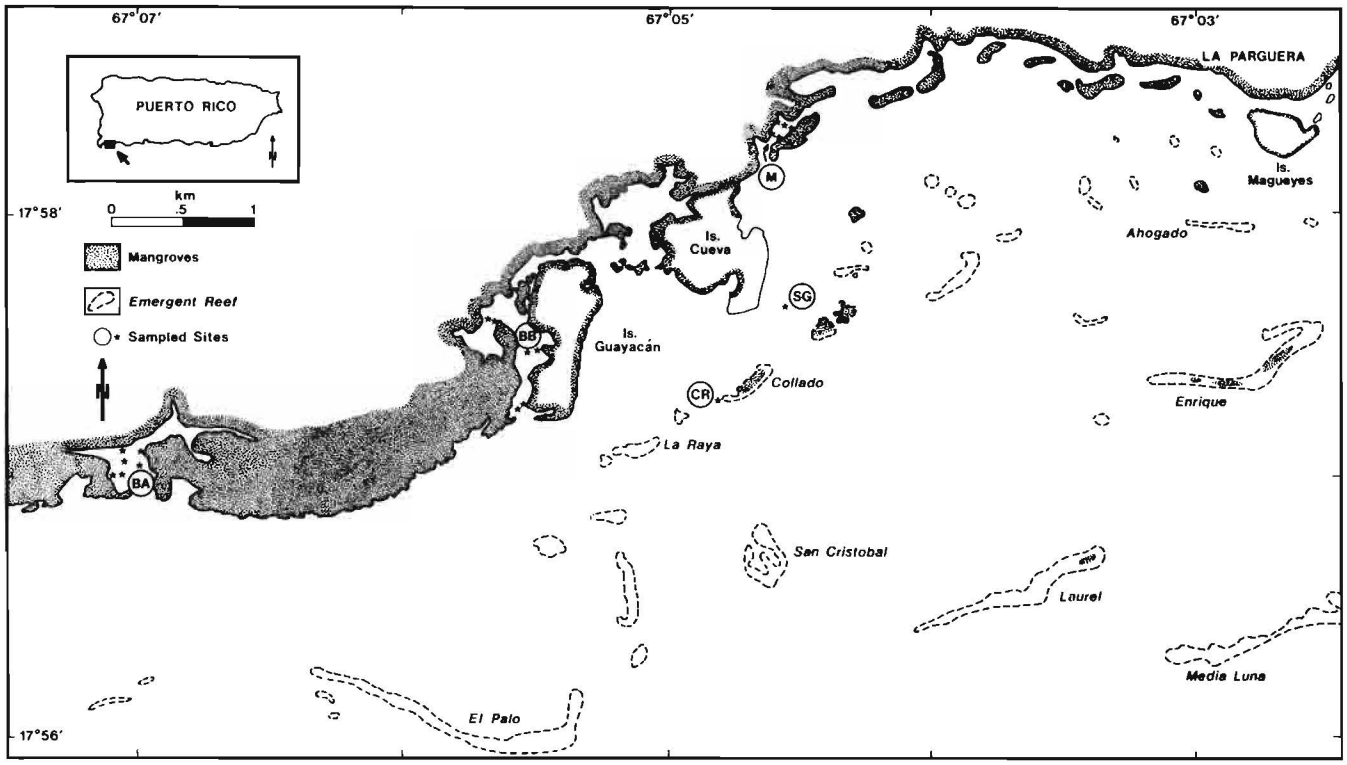

Figure 1

Map of sampling area in southwestern Puerto Rico. M is the primary mangrove sampling site (4 prop-root stations and one lagoon station). BA and BB are additional mangrove lagoons. SG is the seagrass bed station and CR is the coral reef station.

was over soft mud and had a depth of 2 m. One lagoon station was established near the center of the east entrance to the lagoon. Two additional mangrove lagoons to the west of the primary lagoon were also sampled (Fig. 1). They also had a soft mud bottom and an average depth of 1 m.

A seagrass bed station (Fig. 1) was selected off Isla Cueva on a shallow platform primarily covered with *Thalassia testudinum* and some small gorgonians and coral patches. Water depth at this site was 1.5 m.

A coral reef station was located on a fringing reef off the leeward end of a mangrove cay (Fig. 1). The reef was dominated by *Acropora palmata* and *Millepora* spp. The sample site was directly over coral in a water depth of 1.7 m. Adjacent to the reef the bottom was covered with seagrass.

Sampling Methods

We used a lift-net with a night light as a sampling device, composed of a floating platform housing a circular 12-volt sealed-beam automobile headlight bulb (Fig. 2). A standard 50-cm diameter by 165-cm long conical plankton net of 500-micron mesh was attached to the platform by four guide ropes. Power for the light was supplied by a 12-volt marine battery aboard a 6-m fiber-glass support boat.

Sampling consisted of lowering the plankton net to a depth of one meter or less depending on bottom depth, then turning on the light for 10 minutes. The net was then rapidly hoisted to the surface by hand while the light was still on and it sampled fish in the water column between the net and light source. Sampling characteristics of this device are discussed in detail (D. Goulet et al. 1988).

Three replicates were taken at each station during each sampling period. Coral reef and seagrass bed stations were sampled sequentially with a 10 minute no-light period between replicates; mangrove stations were alternately sampled. The order of station sampling was randomly selected and all samples taken within one day of the new moon from 2000 to 0100 hours.

Monthly samples were collected at the four prop-root mangrove stations in August, September, and October 1987; at one of these stations from September 1987 to February 1989; and at the mangrove lagoon station from October 1987 to February 1989. Two additional mangrove lagoons (Fig. 1) were sampled in February 1989. No samples were taken at the mangrove stations in November 1988. Seagrass bed and coral reef stations were sampled from March 1988 to February 1989. Because of inclement weather and gear failure, samples were missed in August 1988 at the seagrass bed station and in August and September 1988 at the coral reef station. No samples were

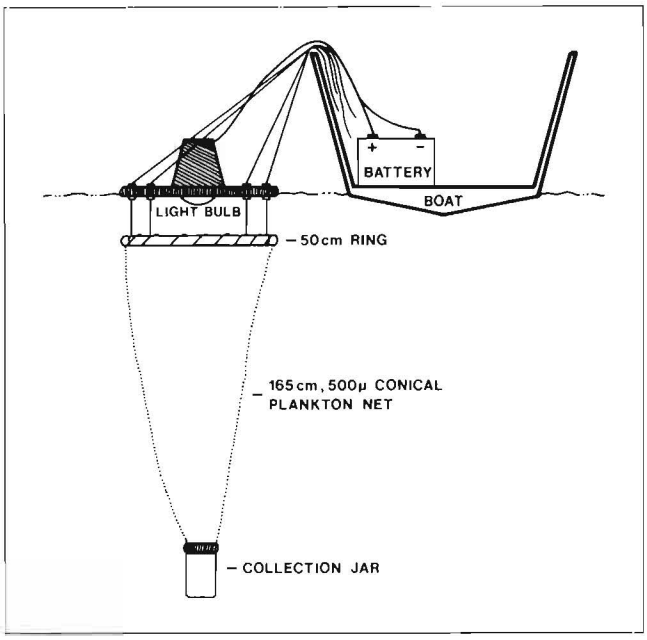

Figure 2
Lift-net sampling device with night light.

taken in January 1989. Water temperature, salinity, and dissolved oxygen were measured at 0.3 m below the surface at each station.

Samples were initially preserved in 10% formalin and transferred to 5% formalin within one week. After sorting, identification, and measurement, the fishes were stored in 70% ethanol. All fishes were identified to the lowest taxon possible. A taxon was defined as a distinct life-history stage of a species. Life-history stages included: preflexion larvae (before notochord flexion), postflexion larvae (after notochord flexion and including flexion larvae), and juveniles (fish with a full complement of adult fin ray counts) (after Leis and Rennis 1983).

We considered mangroves to be spawning areas for fishes if early preflexion larvae were abundant in that habitat. Also, if mangroves are larval nursery areas, then later stage (postflexion) larvae should be abundant there.

Analysis

Two-way ANOVA analyses were carried out on log transformed $(x + 1)$ abundance data for total number of taxa, total number of larvae, total number of non-dwarf herring (*Jenkinsia* spp.) larvae, and the four most abundant taxa, dwarf herring, sardine (*Harengula* spp.), anchovies (*Anchoa* sp.), and bonefish (*Albula vulpes*) to test for differences in abundance among habitats and months. Only the eight months when all habitats were sampled were used in this ANOVA. A two-way ANOVA among the four primary mangrove prop-root stations and months was used to test for significant differences in number of larvae among locations within a mangrove lagoon. Samples were taken during three consecutive months (August–October 1987) for this analysis. Two additional mangrove lagoons (Fig. 1) were compared to Lagoon M during February 1989 with a two-way ANOVA by habitat (lagoon and prop roots) and location (three mangrove lagoons) to test for differences among lagoons. Tukey's HSD test was used to determine which levels of a factor were significant (Sokal and Rohlf 1981).

Additional comparisons of larval abundance were made among habitats (summed over all sampling periods) with a chi-square test assuming larval abundance was proportional to sampling effort.

Similarity among habitats was measured by the percent similarity formula, $PS = 1 - 0.5 \sum |p_{x,i} p_{y,i}|$, where $p_{x,i}$ = proportion of taxa i in habitat x and $p_{y,i}$ = proportion of taxa i in habitat y based on abundance over all sampling periods (Kohn and Riggs 1982). Unweighted pair-group arithmetic average (UPGMA) clustering was used to create the similarity dendrogram (Sneath and Sokal 1973).

Results

Habitats had significantly different patterns of larval fish abundance (Figs. 3 and 4). In all cases there was a significant interaction between habitats and months which indicated that habitats had different trends in larval fish abundance over time (F-test, habitat by month interaction term, $P<0.01$). The mangrove lagoon and prop-root stations differed from coral reef and seagrass bed stations in their patterns of abundance. Larval fish were most abundant at seagrass and coral reef stations from February to April while larvae were most abundant in the mangroves in July (Fig. 3). There was a greater number of taxa at seagrass bed and coral reef stations from December to April, but there was little difference among the four habitats from June to October.

Seasonal patterns of abundance differed among habitats for the most abundant taxa (Fig. 4). From March to April, bonefish larvae were abundant at the coral reef station, but over the whole sampling period they were more commonly collected at the mangrove prop-root station.

Dwarf herring were the most abundant larvae taken, and were primarily collected from seagrass bed and coral reef stations (Fig. 4). Patterns in abundance of dwarf herring larvae (preflexion and postflexion) were similar over time at the coral reef station with a major abundance peak in February 1989 and smaller peaks in May 1988 and October 1988 (Fig. 4). The seagrass bed station differed from the coral reef station in lacking an abundance peak in May 1988 and having a peak in March 1988 (Fig. 4).

The sardine was most commonly collected at mangrove and seagrass bed stations, but few were taken at the coral

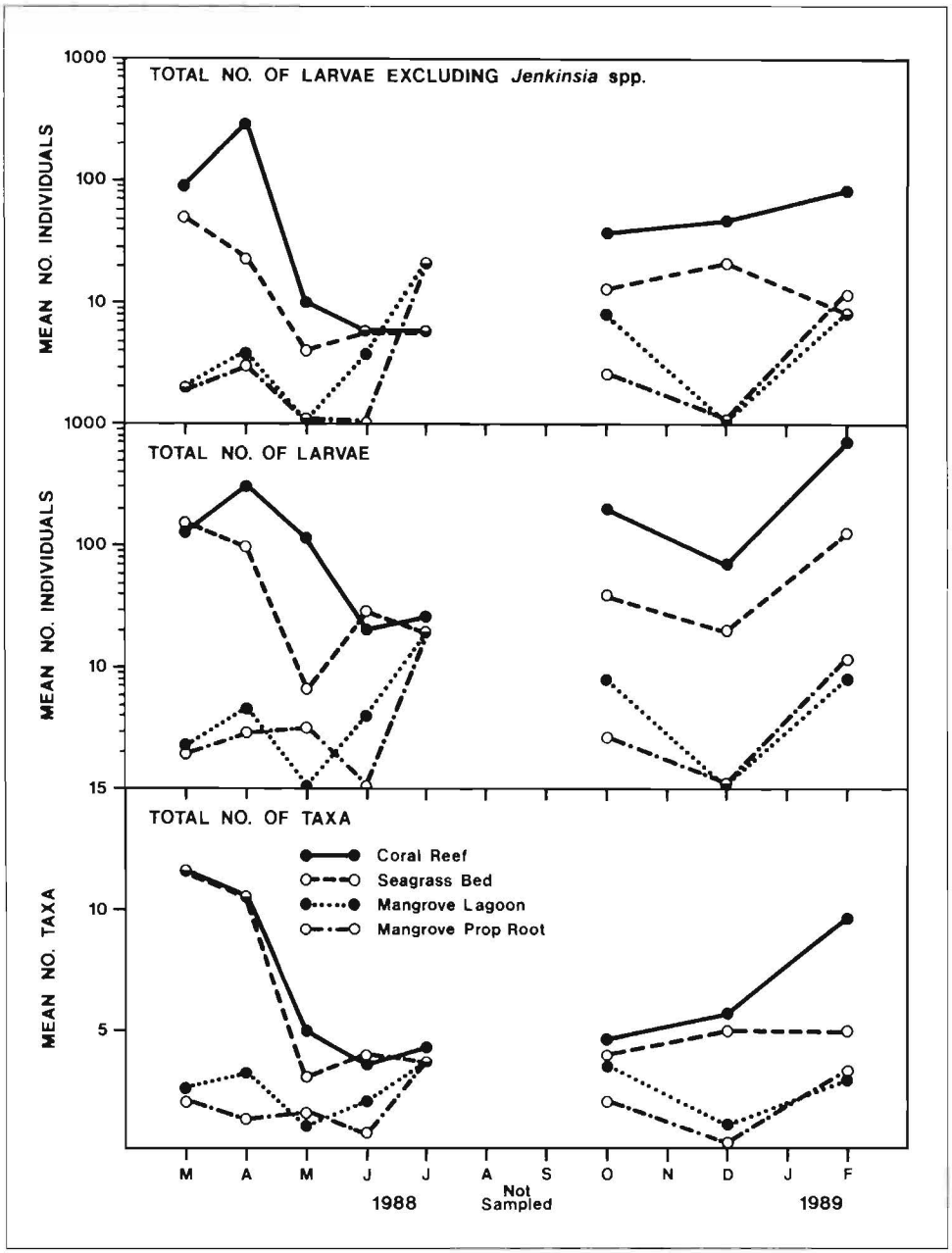

Figure 3
Monthly trends in arithmetic mean number of larvae excluding *Jenkinsia* spp., number of taxa, and number of larvae by habitat.

reef station. The anchovy was primarily collected from mangrove and seagrass bed stations with a major abundance peak in July at mangrove stations and another smaller peak between September and October at seagrass bed and mangrove lagoon stations.

The coral reef station had more preflexion and postflexion larvae than other stations (Chi-square test, $P<0.01$, in both cases). Bonefish (*Albula vulpes*), sea bream (*Archosargus rhomboidalis*), preflexion and postflexion dwarf herring (*Jenkinsia* spp.), preflexion and postflexion silversides (Atherinidae), Clinidae species 1 and 2, and unidentified preflexion larvae, were also significantly more abundant at this station (Table 1) (Chi-square test, $P<0.01$ in all cases). The coral reef station was most similar to the seagrass bed station and very dissimilar to mangrove stations (Fig. 5).

The seagrass bed station had significantly more taxa, preflexion larvae, postflexion larvae, and juveniles than mangrove stations (Table 1) (Chi-square test, $P<0.01$). Four taxa were most common here: Gobiidae species 2, dwarf herring juveniles, and sardine postflexion larvae and juveniles. Also, dwarf herring postflexion larvae were significantly more abundant at this station than at mangrove stations (Chi-square test, $P<0.01$). The seagrass bed station had an intermediate assemblage of larval fishes relative to coral reef and mangroves, but was much more

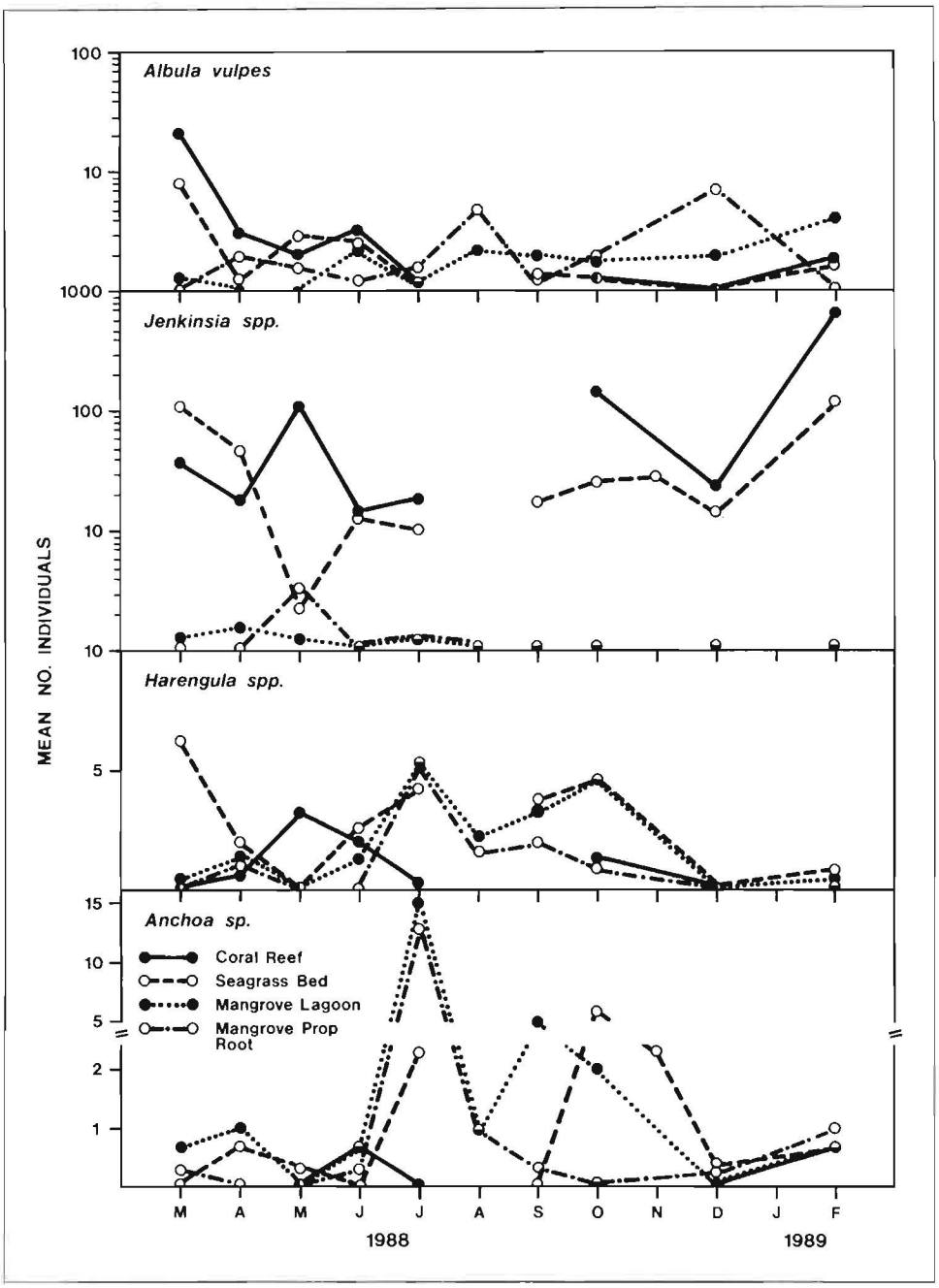

Figure 4
Monthly trends in arithmetic mean number of *Albula vulpes*, *Jenkinsia* spp., *Harengula* spp., and *Anchoa* sp. by habitat.

similar to the coral reef station than the mangrove stations (Fig. 5).

Mangrove stations, in general, had fewer taxa and number of larvae than coral reef and seagrass bed stations (Table 1). The mangrove lagoon had more preflexion larvae and postflexion sardine larvae than the prop-root station (Chi-square test, $P<0.01$ in both cases). Only two taxa were more abundant at the prop-root station, bonefish and gerreid larvae, and the latter was significantly more abundant at the prop-root station than at any other station (Chi-square test, $P<0.01$). Mangrove stations were very similar to each other and next most similar to the seagrass bed station (Fig. 5).

Examination of larval fish abundance within lagoon M at four prop-root stations over a three month period indicated similar trends in larval abundance among stations (F-test, station by month interaction, $P = 0.273$). Months were significantly different in larval fish abundance (F-test, $P = 0.012$), but there was only a marginally significant difference among stations (F-test, $P = 0.041$).

Comparison of larval fish abundance among three mangrove lagoons indicated no interaction between habitats

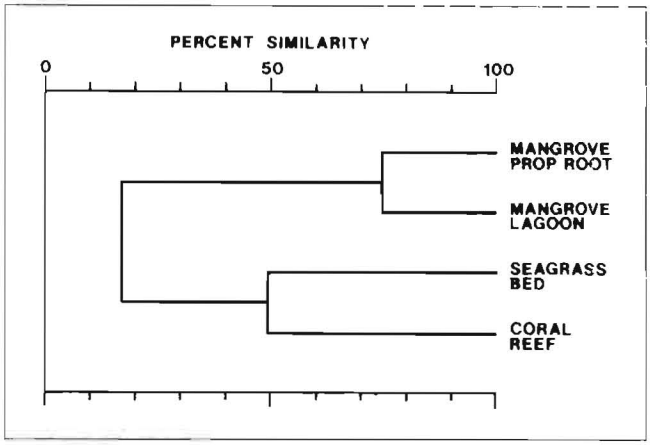

Figure 5
Similarity among habitats based on taxon abundance over all sampling periods. Dendrogram formed by UPGMA method on percent similarity (PS).

and locations (F-test, $P = 0.553$) and no significant difference between habitats (F-test, $P = 0.629$). There was a significant difference in larval fish abundance among lagoons with the primary sampling lagoon (M) having significantly more larvae than the other two (F-test, $P = 0.012$, Tukey's HSD test, Sokal and Rohlf 1981).

Salinity was high (34–37 ppt) at all stations, even during the rainy season. Water temperature during the study ranged from a low of 26.0°C in January–February to a high of 30.5°C in July, but differed less than 1°C among stations during any sampling period. Dissolved oxygen usually ranged from 5 to 7 ppm, but on one occasion measured 2.5 ppm near bottom at a mangrove prop-root station. There was little variation in environmental parameters among stations within any sampling period.

Discussion

Almost any active method of collecting ichthyoplankton in waters with obstructions will result in sampling difficulties. One solution to this problem is the use of a passive aggregating device, such as light. Its application has been primarily relegated to a qualitative, ancillary role in the past. Using light as a quantitative method of sampling can been criticized on two main points: volume sampled is unknown and species selectivity bias.

Volume sampled is dependent on water clarity and current speed. Theoretically, more turbid water should result in fewer larvae attracted owing to a smaller area of light influence. Greater current speed should (up to the point where larvae can no longer maintain their position) result in more larvae passing within the sphere of light influence and in potentially being retained in the area for collection. Current velocity in the nearshore environment is primarily a result of daytime wind-driven circulation in locations, such as the Caribbean, where there is a limited tidal range (ca. 0.5 m). Nighttime, usually a period of low wind, further reduces the influence of current speed on volume sampled. In this study we attempted to control these factors by sampling in areas of similar high water clarity and keeping the duration of sampling short (10 minutes).

Light is selective both for taxonomic composition and size. Though taxon selectivity is not well documented, it is known that different stages of some fish species react differently to light (Bulkowski and Meade 1983). Still, there is a tremendous range of taxa collected by light methods (Doherty 1987) and this same bias is known to occur in towed gears (Thayer et al. 1983). In this study forty-five taxa represented by 7342 larvae were taken.

Size selectivity may be species specific and biased toward either smaller or larger size groups in active gears depending on gear type. Larger larvae are usually less well sampled because they avoid the net (Thayer et al. 1983; Gregory and Powles 1988). Methods using light usually catch more later-stage larvae (presettlement) and juveniles than towed-net gears (this study; Doherty 1987) making them potentially complementary methods for sampling larval fishes.

Although the four habitats sampled were only about 2 km apart, they exhibited different patterns in larval fish abundance. Abundance peaked from February to April at coral reef and seagrass bed stations, but peaked in July and August at mangrove stations when densities at coral reef and seagrass bed stations were lowest. The different patterns in these two nearby areas seemed to contradict the idea of passive dispersal of preflexion larvae within the nearshore environment. Normal wind-driven circulation from the southeast should push water (and preflexion larvae) from nearshore reefs and seagrass beds into mangrove areas. This circulation alone would increase the abundance of preflexion larvae in the mangroves. But preflexion dwarf herring larvae were never collected in mangroves, though juveniles and adults commonly occur there. Even between the coral reef and seagrass bed stations there was little coherence in peaks of abundance for preflexion dwarf herring larvae. This species, instead, makes use of epibenthic and benthic areas and therefore may not be subjected to passive transport by currents (Powles 1977; pers. obs.).

The mangrove prop-root habitat had a low density of larval fish, as did the "open water" lagoon station. Yet larval gerreids, bonefish, and sardine made use of the mangrove habitat. The generally low density of larval fishes in mangrove habitats did not support the hypothesis that these areas are nurseries for larval fishes at least in southwestern Puerto Rico. Several studies support our findings. In the Florida Everglades, there were fewer taxa and larvae taken by towed net in mangrove estuaries than in nearshore areas (Collins and Finucane 1984). Highest diver-

Table 1

Number of fishes by taxa collected by night lighting in four nearshore habitats off southwestern Puerto Rico. Mangrove habitats include only the primary mangrove sampling site (see Fig. 1). Life-history stages are PR: preflexion, PO: postflexion, and J: juvenile.

		Habitat				
Taxa	Stage	Coral Reef	Seagrass Bed	Mangrove Lagoon	Mangrove Prop Root	Total
ALBULIDAE *Albula vulpes*	PO	90	51	36	101	278
APOGONIDAE	PO	—	1	—	—	1
ATHERINIDAE	PR	393	35	15	2	445
	PO	29	3	—	1	33
CARANGIDAE	PO	1	—	—	—	1
Oligoplites saurus	J	—	—	3	8	11
Trachinotus sp.	PO	—	—	—	1	1
CLINIDAE Species 1	PO	22	4	—	—	26
Species 2	PO	58	14	—	—	72
CLUPEIDAE *Harengula* spp.	PO	27	90	91	65	273
	J	24	129	106	112	371
Jenkinsia spp.	PR	2216	115	—	—	2331
	PO	1106	1043	8	3	2160
	J	189	324	3	5	521
Opisthonema oglinum	PO	—	—	6	—	6
	J	—	—	2	—	2
DACTYLOSCOPIDAE	PO	1	—	—	—	1
ELOPIDAE *Elops saurus*	PO	1	—	—	—	1
ENGRAULIDAE *Anchoa* sp.	PR	3	2	1	—	6
	PO	2	47	67	54	170
	J	2	7	4	10	23
GERREIDAE	PO	3	5	3	25	36
GOBEISOCIDAE Species 1	PO	6	—	—	—	6
Species 2	PO	13	2	—	—	15
GOBIIDAE Species 1	PO	4	12	—	—	16
Species 2	PR	2	10	—	1	13
	PO	10	71	1	3	85
Species 3	PO	1	3	—	—	4
Species 4	PO	—	1	1	2	4
Species 5	PO	—	1	—	—	1
LUTJANIDAE	PO	3	—	—	1	4
OPHIDIIDAE	PO	2	1	—	—	3
HAEMULIDAE	PO	8	4	—	—	12
MUGILIDAE *Mugil* sp.	PO	1	1	6	2	10
POMACENTRIDAE	PO	—	—	1	—	1
SCARIDAE	PO	2	2	—	—	4
SCORPAENIDAE	PO	1	—	—	—	1
SERRANIDAE *Epinephelus itajara*	PO	—	—	3	—	3
Hypoplectrus sp.	PO	—	1	—	—	1
SPARIDAE *Archosargus rhomboidalis*	PO	101	24	11	21	157
SPHYRAENIDAE *Sphyraena barracuda*	J	—	—	2	2	4
SYNGNATHIDAE	PO	7	1	—	—	8
SYNODONTIDAE *Synodus* sp.	PO	2	—	—	—	2
Undetermined larvae	PR	1000	16	8	1	1025
	PO	3	1	—	—	4
Total No. of Taxa		34	31	21	20	45
Total No. of Larvae		5118	1561	258	405	7342
Preflexion		3614	178	24	4	3820
Postflexion		1504	1383	234	279	3400
Juveniles		215	460	120	137	932
No. of Samples		27	30	45	51	127

sity and abundance of larval fishes was also found at nonestuarine stations by Powell et al. (1989) in Florida Bay, where spawning (based on preflexion larval abundance) occurred in intermediate to high salinities. Flores-Coto et al. (1983) found most larvae in Tamiahua Lagoon (western Gulf of Mexico) to have originated there and few larvae entered the lagoon from nearshore waters. Within Tamiahua Lagoon the greatest abundance of larvae was in the center of the lagoon away from shoreline habitats. The number of fish eggs decreased with increasing estuarine conditions in mangrove areas of Kenya (Little et al. 1988) and India (Krishnamurthy and Jeyaseelan 1981). There was also a gradient from high to low abundance of larval fish from the mouth to upper reaches of a mangrove creek in Kenya (Little et al. 1988).

Patterns of larval fish abundance in tropical nearshore island habitats may be different from tropical or temperate estuaries where migration into the estuaries from nearshore waters is more typical (Weinstein 1979; Weinstein et al. 1980; Shaw et al. 1988). The predominance of reef-associated species and high salinity conditions in tropical nearshore island habitats may account for a limited coupling with the shelf fish assemblage.

Haemulid and lutjanid larvae were noticeably absent from our collection, even though they comprised about 55% of juvenile fishes in mangroves of this area (Dennis, in press). It is possible that these taxa were not attracted to light at the stage they entered the prop-root habitat or settled in other nearby habitats and migrated to the prop roots. In Florida Bay, few snapper larvae were collected in shallow water areas, but preflexion larvae were found at the shelf edge near coral reefs (Powell et al. 1989).

It is also possible that many taxa may recruit to nearshore habitats in short duration periods (ca. 1–3 days) which are easily missed by monthly sampling (Doherty 1987). We observed this phenomenon in September 1988 when three jewfish (*Epinephelus itajara*) larvae were collected at the mangrove lagoon station. The following night we sampled at the marine station dock on Isla Magueyes (a mangrove-fringed island about 3.5 km east of lagoon M) (Fig. 1) and collected three additional jewfish larvae. The third night no jewfish larvae were collected. Though the complete duration of the jewfish recruitment event is not known, probably only fortuitous sample timing leads to capture of this and possibly other species.

Smith et al. (1987) described the nearshore assemblage of fish larvae as differing from that found offshore by being composed of morphologically unspecialized forms that may spend their complete larval phase nearshore. The nearshore larval fish assemblage collected off southwestern Puerto Rico fits this description as it was composed of common shallow-water fish families with few specialized larval forms (e.g., bonefish *leptocephali*, jewfish larvae). Without synoptic sampling across the shelf we are unable to estimate what proportion of the larval fish assemblage might have originated and remained in the nearshore environment, but several taxa, such as bonefish, sardine, jewfish, and lutjanids were collected only at late development stages, an incident which suggests recruitment from outside the nearshore environment. Cross-shelf sampling will be needed before the source of some taxa can be determined.

The lack of many larval fish taxa in mangroves might be attributed to the numerous piscivore predators that reside in mangrove prop roots (Dennis, in press) and to periodically poor environmental conditions. Sluggish water movement and high biological oxygen demand can result in occasionally low oxygen conditions in the mangroves. One incident of depressed dissolved oxygen level (2.5 ppm) was measured near bottom at night in the mangrove prop roots. The effect of low oxygen on ichthyoplankton should be ascertained before there is further judgment on the quality of mangrove areas as nursery grounds for larval fishes.

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