Description of larval development of the red hind *Epinephelus guttatus*, and the spatio-temporal distributions of ichthyoplankton during a red hind spawning aggregations off La Parguera, Puerto Rico

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DESCRIPTION OF LARVAL DEVELOPMENT OF THE RED HIND, *Epinephelus guttatus*, AND THE SPATIO-TEMPORAL DISTRIBUTIONS OF ICHTHYOPLANKTON DURING A RED HIND SPAWNING AGGREGATION OFF LA PARGUERA, PUERTO RICO

by

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ABSTRACT

Coral reef fishes exist as open populations, with connections among areas maintained by pelagic larval dispersal. Key questions are the extent and variability of these connections and at what scale are local populations self-recruiting. The discrete spawning behavior of the red hind was used to address these questions off southwest Puerto Rico. Laboratory larval-rearing indicated the conditions under which development may occur, the timeframe for interpreting the extent of larval swimming and feeding, and descriptions to aid identification of field-caught individuals. At 26.2-25°C, red hind eggs (0.95mm) hatched in 24 hr. Early free embryos were positively buoyant. At 45 hr (2.28mm TL) they could change and maintain vertical position. Larvae at 70 hrs (2.48mm TL) had well-developed pectoral fins, a broadened caudal finfold, and a fully-functional mouth and digestive system. Larvae were capable of swimming and searching for food. Larvae (2.91mm TL) showed no sign of urostyle flexion at 82 hr, when the last specimens died. Spatio-temporal variations in egg abundance indicated red hind spawning in 1997 occurred around full moon in February, when the mixed layer showed minimum temperatures (25.5-26°C) and highest chlorophyll-a concentrations over the outer shelf, where spawning occurs. Larval abundance of all taxa declined offshore (out to 22 km) and no advanced Epinephelinae larvae were recorded. Rather, a strong westward current resulting from strong winds and far-field mesoscale eddies impinging on the coast is thought to have rapidly dispersed eggs and larvae to the west, but also to have kept larvae near the shelfedge for potential retention at sites along the west coast.

During late March/early April there was a period of calm currents followed by a current reversal as smaller eddies were set up along the southwest coast. At this time there were large increases in the number of pre- and especially post-flexion larvae encountered across all taxa, suggesting these currents enhanced larval retention of species spawning at this time. Larval data and current flows indicate that recruitment should be variable depending upon immediate conditions and that retention within Puerto Rico could be both local or up to 60km downstream, with some further transport possible.

RESUMEN

Los peces de arrecifes de coral existen como poblaciones abiertas, con conexiones entre áreas mantenidas por dispersión de larvas pelágicas. Las preguntas claves son ¿qué grado de conectividad? y ¿a cuál escala las poblaciones locales se auto-reclutan? El comportamiento de desove discreto de la cabrilla se utilizó para orientar estas preguntas al suroeste de Puerto Rico. Las condiciones bajo las cuales el desarrollo larval puede ocurrir, el marco de tiempo para interpretar la capacidad de natación y alimentación, y las descripciones que permiten la identificación de individuos capturados en el campo, se obtuvieron por medio de cultivo en laboratorio. Los huevos (0.95mm) a 26.2-25°C eclosionaron en 24 horas. Al inicio, los embriones libres tuvieron flotación positiva. A las 45 horas (2.28mm LT) pudieron cambiar y mantener su posición vertical. Ya larvas a las 70 horas (2.48mm LT), mostraron su boca y sistema digestivo completamente funcional, las aletas pectorales bien desarrolladas y ensanchamiento de su aleta caudal. Las larvas desarrollaron capacidad de natación y de búsqueda de alimento. A las 82 horas (2.91mm LT), cuando los últimos especímenes murieron, las larvas no mostraron flexión del urostilo. Las variaciones espacio-temporales de abundancias de huevos indican que en 1997 el desove de la cabrilla ocurrió alrededor de la luna llena de febrero, cuando la capa mixta mostró las temperaturas mínimas (25.5-26°C) y las mayores concentraciones de clorofila-a sobre el borde de la plataforma. La abundancia total de larvas declinó fuera de la costa (hasta 22 km) y no se registraron larvas Epinephelinae avanzadas. Se piensa que fuertes corrientes hacia el oeste resultante de fuertes vientos y de giros a mesoescala impactando la

costa, dispersaron los huevos y las larvas hacia el oeste. Pero además, las mantuvieron cercanas al veril para una retención potencial en sitios cercanos a lo largo del suroeste costero. Un período de calma de corrientes seguido por una reversión de corrientes, así como pequeños giros, se establecieron en el área a finales de marzo y principios de abril. En este momento el número de larvas pre- y especialmente post-flexión incrementó en todos los taxones, sugiriendo que la retención de especies desovando en ese momento se acrecentó. Los datos larvales y de flujos de corrientes indican que el reclutamiento debe ser variable, en dependencia a las condiciones inmediatas y que la retención podría ser local o hasta 60km en dirección de la corriente, con la posibilidad de algún transporte más distante.

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DEDICATION

A mis adorados hijos Brenda, Vanessa y Edgardo E. y mi amada esposa Belkis les dedico este trabajo como un premio al sacrificio familiar. Sin la ayuda, el aliento y la comprensión de ellos no hubiera podido alcanzar este grado, ni tener la satisfacción de servirles de ejemplo en el desempeño de sus vidas profesionales.

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CHAPTER I

INTRODUCTION

Reef fishes are among the most valuable resources in tropical coastal areas. They sustain important commercial and recreational fisheries and represent substantial sources of protein (if consumed locally) or foreign exchange (if exported or used to support tourist activities). Reef fish resources, as with other fishes, are threatened by a high rate of exploitation and degradation of their essential habitats. Among the most vulnerable, yet valuable species are the groupers (Sadovy, 1994). Protection of their essential habitat has become a management priority within U.S. waters. In addition, the use of marine reserves as management tools has gained acceptance in recent years (Roberts et al., 1995). In part, to aid in habitat protection and sustained production (Bohnsack, 1996).

When implementing a Marine Protected Area (MPA) as a management tool, one of the main expectations is the increase in spawning stock biomass and subsequent reproductive output. One potential benefit is increased productivity from increased recruitment. Several questions arise from this premise: a) are larvae recruiting in an area the result of local spawnings, b) do larvae come from distant spawning grounds, or c) is there a combination of both types of contributions? Dispersal plays a crucial role in several aspects of the biology, management and conservation of many species, including coral reef fishes and other demersal marine organisms with pelagic larval stages. To know the origin of propagules that replenish benthic populations is a major challenge. While earlier studies emphasized the broadly extensive dispersal of reef fish larvae, recent publications have emphasized the extent to which these larvae succeed in returning to their natal populations (Cowen et al., 2000; Swearer et al., 1999; Warner and Cowen, 2002; Swearer et al., 2002; Sponaugle et al., 2002; Mora and Sale, 2002).

One criterion for MPA site selection is whether larvae recruit back to the area, i.e., does self-recruitment occurs? Of specific importance in the area proposed is the occurrence of critical spawning events from overfished threatened species, such as grouper spawning aggregations. A MPA has been proposed in La Parguera, Puerto Rico in the Turrumote Cay. The issue of self-recruitment is important to resource management and should be considered for the proposed MPA. If self-recruitment is significant, then fisheries could be managed locally, independently of neighboring areas or islands by appropriate conservation measures. But if most of the recruiting larvae arrive from external sources, then regional management of the resources, including networks of MPA's, would be necessary.

Little is known of the biology of the early life history stages of most tropical reef fishes. This is largely due to their small size, relative inaccessibility, and the great difficulty involved with maintaining or rearing them in the laboratory (Jones, 1993). Larvae of reef fishes are difficult to collect, since most species are relatively uncommon in plankton tows and are very difficult to identify, particularly to taxa below the family level. Most eggs of reef fishes obtained from ichthyoplankton collections are not identifiable to any taxon. Larval stages of marine fishes are tremendously diverse in morphology. Since they are also often strikingly dissimilar to their adult forms, identification is usually very difficult. Larval adaptations and metamorphic transformations further complicate the life histories of many species, relatively few of which have been adequately described.

Studies concerned with the pelagic stages of marine fishes span a wide range of research topics, from basic investigations in developmental biology to applications in fisheries techniques to analysis of systematic relationships. Yet, before such studies can be initiated, the development and identification of the early life history stages of the species under investigation must be elucidated. Ontogenic studies of fishes are usually based on earlier works that have employed meristic and morphometric analysis; both are equally essential for identification and systematic analysis (Sanknop et al., 1984). Information on early life history stages exists for less than one-tenth of all perciform species.

Spatio-temporal distribution patterns and abundances of fish larvae are influenced by the interaction of diverse biotic and abiotic processes. The biological factors include the location and time of spawning, adult spawning strategies, the type and size of the eggs, duration of the larval period, larval behavior, predation rates, growth and feeding (Leis, 1991; Shulman and Bermingham, 1995). Physical factors include currents, winds, gyres, upwelling, water column stratification, internal waves and topography of the bottom. The interaction of these factors can influence the horizontal and vertical distribution and the movements of fish larvae, producing a great diversity in dispersion patterns (Gray, 1993).

Three different reproductive/larval strategies can be distinguished relative to dispersal processes of marine fish larvae: (1) demersal spawners; (2) pelagic spawners with short larval duration; and (3) pelagic spawners with long larval duration, where the morphologic differences suggests some degree of adaptation for the larvae to be easily carried by the currents (Smith et al., 1987). Demersal eggs tend to have larger sizes, and resulting larvae at hatching are much more developed in sensorial and swimming capabilities, so they can actively move before larvae from pelagic eggs (McFarland et al., 1985). For pelagic eggs, differences in specific gravity between eggs and sea water influence their vertical distribution (Coombs, 1981; Henri et al., 1985; Nielson et al., 1986; Frank and McRuer, 1989; Page et al., 1989).

Although variable, pelagic eggs are generally buoyant in seawater during most of their development, with a tendency to increase their specific gravity as they get closer to eclosion (Coombs, 1981). Scalafani et al. (1993) investigated the effects of larval buoyancy between the stages of absorption of the viteline sack and the development of a functional gas bladder to explain day/night vertical migrations. However, they based their dispersion model on Lagrangian movements due to changes of density, without taking into account active larval swimming capacity.

Larval size at the moment of first feeding and the time available to find food before an irreversible process of lethargy begins, is in great measure determined by the size and nutrient quality of the egg and by water temperature (Lasker, 1981). Generally, larvae from larger eggs have more time to find food, since the viteline sack remains after their exogenous feeding begins. Thus, the larvae have more available energy for metabolism (May, 1971). The duration of egg incubation (time they drift passively), although highly influenced by temperature, is also influenced by egg size. The size at which larvae hatch diminishes with increasing temperature and also influences the buoyancy of eggs and therefore their vertical distribution (Blaxter, 1992). Larval swimming capacity also influences in the spatio-temporal dispersal patterns. Laboratory studies have shown that fish in pre-settlement stages are strong swimmers that can sustain speeds from 0.1 to 0.4 m s^{-1} for several days (Wolanski et al., 1996; Stobutzki and Bellwood, 1994). It is clear that at the end of the pelagic phase, reef fishes are not passive, since they are able to control their vertical position in the water column (Leis, 1982, 1991). This depends on their locomotion capacity and sensorial abilities; although at present, little is known of these abilities (Stobutzki and Bellwood, 1994).

Spatio-temporal distributions of different species vary according to their peculiar ontogenetic development strategies. Leis and Miller (1976) found a pronounced coastal-oceanic gradient distribution for most fish larvae in Hawaii. Those with neritic pelagic habits were evenly distributed in relation to the distance from the coast. Reef fish larvae with pelagic eggs were more abundant offshore. These results agree with those obtained in La Parguera by Ramírez (2000), where most fishes with pelagic eggs have a distribution further from shore, while the demersal spawners and estuarine species are mainly found inshore. Their results also suggest that, although the offshore distribution is the dominant pattern for most reef fish taxa, there exists a substantial population variability in horizontal and vertical ontogenetic distributions.

These recent studies also question Smith et al.'s (1987) characterization of two types of pelagically spawned larvae: 1) those morphologically modified (fins spinations, cranial armor, pedunculated and/or elliptic eyes, dorsal pigments, long intestines), or with specialized behavior to be transported by currents at long distances, the “far field assemblage”, and 2) those not specialized that avoid the currents and live near to reefs, the “nearfield assemblage”. Snappers (*Lutjanidae*) and groupers (*Serranidae*) are representative families of the first group for their morphologic specialization (opercular and fin spination), but they are notable for their scarcity in offshore samples (Ramírez, 2000).

Different theories have been tested to explain the factors that govern the pelagic dispersal, retention and return settlement of reef fish larvae. Cowen and Castro (1994) and Sponaugle and Cowen (1996) hypothesized larval retention in Barbados by showing an agreement among the distribution of reefs fish larvae with convergences of flows moving away from the coast and subsequent return flows. Important factors contributing to larval retention were the topographical variations that included onshore current flow at certain depths, the synchronization of spawning to the lunar tide cycle, and the active or passive behavior of competent larvae.

Another mechanism that influences the spatio-temporal distribution of larvae, the recruitment processes, and in great measure the degree of retention is the effect of internal waves (Pineda, 1991; Shanks, 1983), and these phenomena may be specifically significant in Puerto Rico (Giese et al., 1990; Capella, com. pers.). During their pre-settlement stage, reef fish larvae could synchronize their active swimming behavior to be transported by these waves onshore to facilitate the recruitment process.

The Family Serranidae comprises one of the most valuable commercial and recreational marine fishes in the world. Most species are tropical, but several occur in temperate waters and a few enter freshwater (Richards, 1994). The family is very large, with about 62 genera and 449 species worldwide, and is divided into the following five subfamilies (following Eschmeyer 1990): Serraninae, Anthiinae, Epinephelinae, Liopropomatinae, and Grammistinae. These are convenient because the larvae are distinct for each subfamily. Eggs are poorly known and resemble the general percoid egg of tropical waters being about 1mm in diameter with a clear shell and very narrow periviteline space (Richards, 1994). Development is presumed to be very rapid thus making eggs especially difficult to identify. Larvae are rather distinct for each subfamily. Epinepheline larvae are very unique, having long dorsal and pelvic spines, which often bear spinelets, and being moderately deep bodied and compressed, giving a kite-like appearance.

The American representatives of the subfamily Epinephelinae (Serranidae) are comprised of three genera, 5 subgenera and 21 species, and although there are considerable differences in size and adult body forms, their larvae are similar and no obvious characters are available to separate larvae more than the genus level (Kendall, 1979). According to Kendall (1979) this subgenera possesses a series of specialized characteristics that seemingly would allow them to have a long pelagic existence. However, the morphologic adaptations for pelagic life observed in the Serranidae (spination in fins and in the head bones), are not necessarily related to their pelagic phase duration. These structures, besides increasing the apparent size of the larva when extended, can be used for protection against predators. Another effect of these ornamentations is to increase relative density, which would need be accompanied by the development of the gas bladder in order to control vertical distribution in the water column (Lasker, 1981). Although Kendall (1979) offers distinctive characters at the group level, he does not present detailed descriptions or ontogenetic development series for the Epinephelinae subgenera. Likewise, other studies reported the laboratory culture of *Epinephelus striatus* (Tucker, 1991; Tucker, 1994; Callum et al., 1995; Tucker and Woodward, 1996) but did not describe its ontogenetic development.

The red hind *Epinephelus guttatus* (Figure 1) is among the most commercially and recreationally important species of the shallow water reef fisheries in the Caribbean, the Bahamas, and Bermuda (Appeldoorn et al., 1992; Appeldoorn and Valdés-Pizzini, 1996). Currently, red hind constitutes one-third of the total grouper landings in Puerto Rico and ranks as one of the top five species of the commercial fisheries of the U.S. Virgin Islands (Appeldoorn et al., 1992). Recreational catches are not recorded in statistics collected by the P. R. Fisheries Research Laboratory (DNER), but this species ranked fourth in a recent survey of recreational finfish fishing in Puerto Rico (Appeldoorn and Valdés-Pizzini, 1996). Since recreational catches go unreported, the stock status could be more exploited than generally estimated.

Figure 1. *Epinephelus guttatus* (Red hind)

Assessments carried out in the late 1980's in Puerto Rico and Virgin Islands indicate that red hind stocks are both growth and recruitment overfished (Beets and Friedlander, 1992; Sadovy and Figuerola, 1992). The Caribbean Fishery Management Council has implemented seasonal closures to protect aggregation sites in the Federal waters of Puerto Rico and St. Thomas in response to concerns over declining mean sizes and highly female biased sex ratios (CFMC, 1996).

The red hind is slow growing and long-lived (Thompson and Munro, 1978; Sadovy et al., 1992). It lives as long as 18 years in the USVI and Puerto Rico (Sadovy et al., 1992). The red hind is a protogynous hermaphrodite that forms spawning aggregations in winter (Sadovy et al., 1994). Adult red hind are often associated with rocky coral reefs areas in relatively shallow waters and are basically sedentary unless foraging (Bolden, 1994). During the non-reproductive season, red hind living inshore have overlapping home ranges with little contact between individuals (García-Moliner, 1986). Population sex ratios are typically female biased: 1:3.25 (males: females, N= 510) for the west coast of Puerto Rico (Sadovy et al., 1994). The minimum size of red hind at sexual maturation is 195 mm FL, with 50% of the individuals mature at 215 mm (Sadovy et al., 1994). At spawning, gametes are released in discrete patches during the evening; planktonic larval duration is 30 to 45 days (Colin et al., 1987). Standard lengths ranged from 123-332 mm for females, 193-307 mm for transitionals, and 207-349 for males. The mean (± SD) lengths for females, transitionals and males were: 217 ±30 mm, 243 ±33 mm, and 265 ± 33 mm, respectively (Shapiro et al., 1993c). *E. guttatus* ranges between North Carolina to Rio de Janeiro, Brazil, including the Gulf of Mexico. In Puerto Rico the red hind is found all around the island, and several spawning grounds have been identified, but those most thoroughly documented are from the southwest coast.

Sadovy et al. (1994) reported a three-month period over which ripe ovaries are found in *Epinephelus guttatus* in Puerto Rico while the reproductive activity is limited to only two weeks every year during the aggregation period, where they can spawn more than once (Shapiro et al. 1993a). The red hind, which is a protogynous hermaphrodite, spawns in Puerto Rico at the end of January and beginning of February (Shapiro et al., 1993a, and Sadovy et al., 1994). Increases in red hind densities were observed in "El Hoyo" La Parguera, Puerto Rico, four days before the full moon in January 1984, reaching 7.6 per 100 m^2 during the full moon, gradually decreasing during the two following days (Shapiro et al., 1993b). Although the spawning activity was not observed at this time, they presume that it happened during the night of full moon.

For Puerto Rico, Munro et al. (1973) and Colin and Clavijo (1988) reported that spawning aggregations occur when water temperatures were minimum, with peak spawning in February. During the last decade commercial fishermen and investigators in Puerto Rico have noted a marked variability in the timing of spawning, i.e. local fishermen from the west coast area noticed that the red hind spawning aggregations peaked in mid March and not in February for 1998. Rosario (Fisheries Laboratory, DNER-PR, pers. comm.) corroborated this information by monitoring gonadosomatic indices. While variations in the timing of minimum water temperature (as an environmental cue for reproduction), has been raised to explain the delay during this and other years, such variability may also be indicative of pending collapse of the aggregation.

Aggregations typically form in the vicinity of the edge of the insular platform at depths of 10 and 50 fathoms near the full moon in December, January and February (Shapiro et al., 1993a; Colin et al., 1987; Sadovy et al., 1994). In the cooler region of Bermuda, aggregation and spawning occur from April to July, thus perhaps indicating a preference for specific temperature ranges. The shortest days of the year and the lowest water temperatures characterize the period in Puerto Rico (Figures 2a and 2b).

The adult meristics for the *Epinephelus guttatus* are: a) 10 pre-caudal vertebrae and 14 caudal with a total of 24 vertebrae, b) the first dorsal fin have XI spines and the second dorsal fin 18 to 20 soft rays, c) the anal fin has three spines with 9 (8-10) rays, d) the pectoral fin is sustained by 18-19 rays, e) the gill rakers are constituted with 7+14=19-20 in its meristics, and f) the lateral line has 115-125 scales. Some of these meristics are useful for identification during early development once the specific character has been fully developed. Partial descriptions of post-flexion larvae were found in Richards, (1994) (from Johnson and Keener, 1984).

A **B**

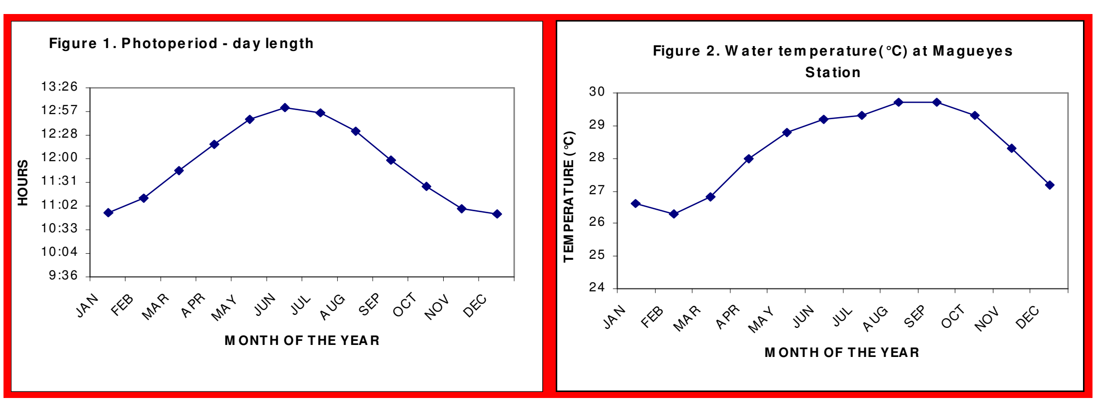


Figure 2. A) Photoperiod (day length) by month in Puerto Rico. **B**) Mean monthly coastal water temperature at the Magueyes station, La Parguera, Puerto Rico, during 1997.

At present there is little information on the spatio-temporal distribution of the *Epinephelus guttatus*, nor is there information on the behavior of their eggs and larvae during their pelagic phase. Furthermore, a complete description of the ontogenetic development of the red hind does not exist, although Richards et al. (1994) presented an incomplete series of post-flexion larvae (insufficient to identify early developmental stages). At best, the presence of serranines and some epinephelids have been recognized by their general characteristics at family level (e.g., for Puerto Rico, García et al., 1995; Ramírez, 2000; González, 2002; Rojas, 2002).

The overall goal of this study was to characterize temporal variations in ichthyoplankton distributions off of La Parguera over the short-term and to relate these to the hydrodynamics conditions and forces prevailing or governing egg and larval dispersal at different scales. In particular, the timing of this study was chosen to correspond to the spawning season of the red hind, *Epinephelus guttatus,* and the location of sampling was centered around the known shelfedge spawning aggregation site known as "El Hoyo" (Figure 3). Thus, the study concentrates especially on the dispersal of red hind eggs and larvae. The findings will contribute to understanding of the processes affecting retention/dispersal and the extent to which this species functions as an open (connectivity) or closed (self replenishment) population.

The approach of focusing on a particular species using sampling with high temporal resolution and concurrent observations on physical oceanographic parameters sets this study apart from more typical larval surveys that have been done in the region (Richards 1984, Smith et al. 1987, Ramírez 2000, González 2002, Rojas 2002). Most notable is that of Ramírez (2000) who studied larval fish distributions in the same area, but only at broadly-spaced intervals (Feb/95, Dec/95 and May/96). Thus, while she was able to characterize seasonal variations in the ichthyoplankton communities and their spatial relationship with respect to a neritic-oceanic gradient, she was not able to assess the role that oceanographic processes had on these distributions nor their changes over the short term. Rojas (2002) made a similar spatial characterization in the Mona Passage, immediately west of La Parguera, but only for one time period (Oct/00). Immediately to the east of La Parguera, off Guayanilla Bay, González (2002) studied long-term temporal variations (bi-monthly sampling) in the ichthyoplankton community, but only at one offshore station. None of these studies were focused at temporal scales appropriate for determining the sequence of egg and larval dispersal for a single taxa and the physical processes affecting observed distributions. In contrast to the above, the present study is more similar to the work of Cowen and Castro (1994), Sponaugle and Cowen (1996) and Sponaugle et al. 2002), who studied the processes affecting larval dispersal/retention of damselfishes off Barbados at temporal scales relevant to their ontogenetic development and their limited spawning period over the lunar cycle. However, damselfish spawn benthic eggs that hatch at an advanced stage of development, resulting in a shorter larval duration and larvae with greater swimming capabilities. Thus, it is likely that the results of their work will not be directly reflective of the processes affecting the dispersal of pelagically-spawned eggs and larvae and their resulting temporal and spatial distributions.

The specific objectives of this study were: 1) to target the full pelagic phase of a single species, the red hind, along an inshore-offshore gradient off La Parguera, 2) to characterize the prevailing oceanographic and hydrodynamic conditions that governed the retention/dispersal behavior of eggs and larvae during the red hind spawning season 3) to characterize the temporal variations in ichthyoplankton composition and its relation to the prevailing oceanographic conditions. To specifically work with red hind eggs and larvae required the ability to identify these, and complete descriptions were not available in the literature, especially of the early stages. Thus, a fourth specific objective was the description of larval development of the red hind.

The brief availability of eggs and larvae as part of the plankton that characterizes the reproduction behavior of the red hind, in some way hinders the study on these stages. However, it also offers the unique advantage that the date and elapsed time of eggs and larvae after fertilization are accurately known, as well as their geographic position in relation to the spawning grounds. An additional advantage is the absence of overlapping cohorts produced from multiple spawning events over the year, which can obscure age and growth patterns and patterns of ontogenetic development or retention/dispersal, under different oceanographic conditions that could prevail at different yearly season.

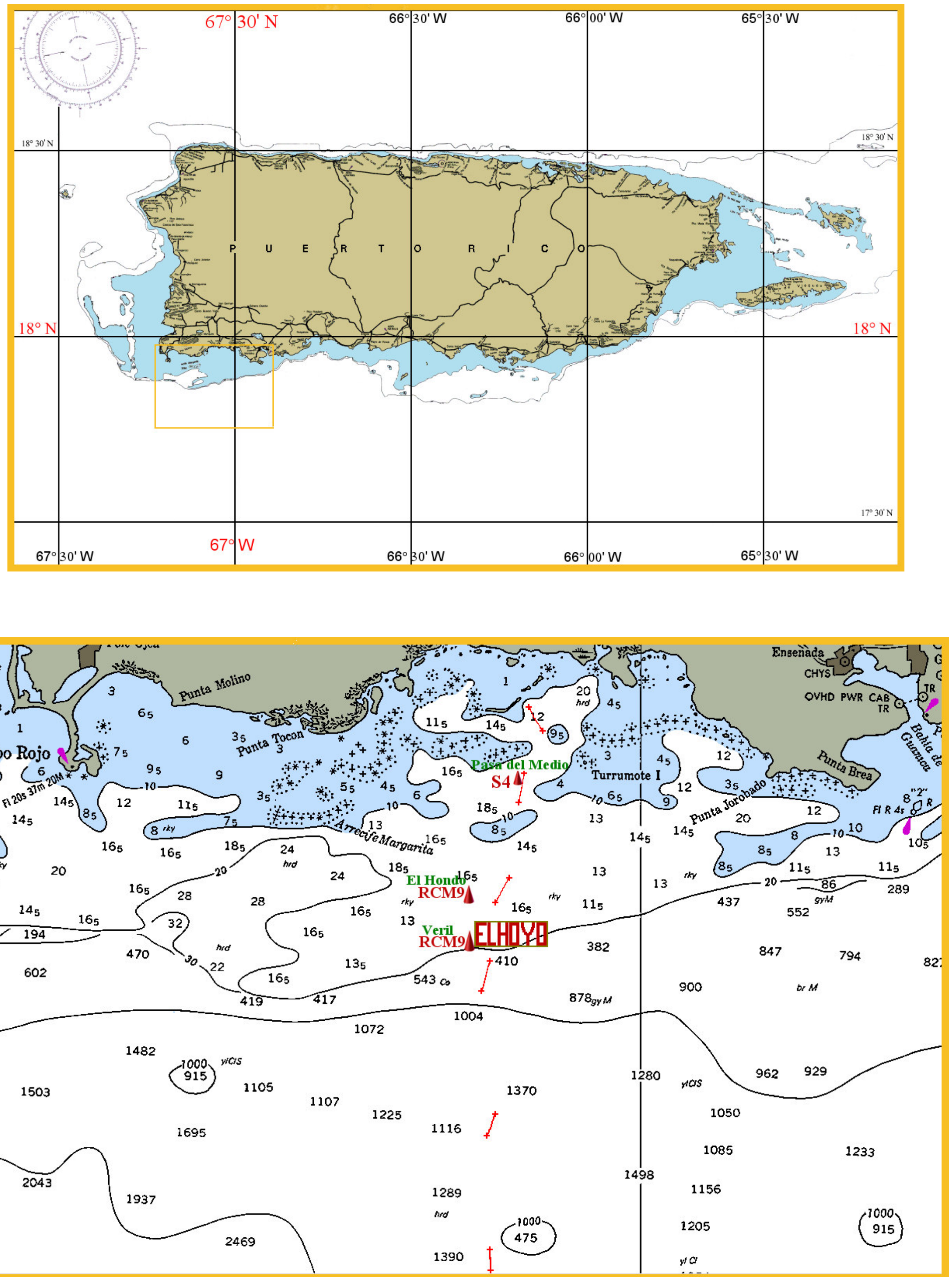


Figure 3. Study site and location of ichthyoplankton sampling stations at La Parguera Bay, southwest of Puerto Rico. (January 24 to April 10, 1997). Current meters are represented by cones.

CHAPTER II

DESCRIPTION OF THE ONTOGENETIC DEVELOPMENT OF THE RED HIND *Epinephelus guttatus*, UNDER LABORATORY REARING CONDITIONS

INTRODUCTION

The study of reef fish larval behavior and dispersal patterns requires that specimens be identifiable. One method for developing larval descriptions is to rear eggs and larvae in laboratory. However, the larval culture of groupers (Serranidae: Epinephelinae) is difficult because they are among the smallest marine fish larvae, with corresponding small mouth sizes and limited yolk reserves (Duray et al., 1997). Typically, the larval period is relatively long, and groupers require live food longer than most reared marine fish. Hatchlings become free-swimming and pigmented on the third day, and begin to feed on exogenous food organisms between the third and fourth day, prior to total yolk sac absorption (Kuo, 1995).

Larval culture requires a supply of fresh sperm and eggs. During spawning aggregations, ripe red hind males discharge copious sperm with little pressure applied to the abdomen; ripe females discharge a stream of clear eggs with firm pressure applied to the abdomen. Artificial fertilization has been carried out in the field by stripping eggs and sperm into a plastic bag (Colin et al., 1987). Fertilization rates were nearly 100%; fertilization rates were about 50% from stripped animals that had been dead for three hours. Red hind has been induced to spawn in Bermuda with two injections of human chorionic gonadotropin (HCG) of 700 IU HCG/kg body weight (Tucker, 1994). Nassau grouper *Epinephelus striatus* have been spawned by using HCG, and had a fertilization rate of 85% (Tucker and Jory, 1991; Tucker et al., 1993). Survival rate from fertilization to first feeding, for six spawns, varied from 73% to 94%. Nassau grouper have been induced to spawn voluntarily in captivity by manipulating water temperature (Tucker et al., 1996). Other serranids have also been induced to spawn in captivity by using hormone (Tucker, 1994).

Colin et al. (1987) hatched red hind eggs and cultured the larvae for 11 days. They reported that the nearly spherical unpigmented eggs ranged from 0.96-0.97 mm in size; a 0.22 mm diameter single oil globule was present while some had multiple, smaller oil globules; the perivitelline was about 0.01 mm wide; and the blastodisc was about 0.625 mm in diameter. Eggs hatched 27 h after fertilization at 26.5^{o}C and 31 h at 25.5 ^{o}C. The larvae did well initially and fed actively on zooplankton as evidenced by feeding strikes. After 6-7 days, mortality greatly increased so that by day 11 only a few larvae remained. Prey size is important to larval survival (Watanabe et al., 1996; Duray et al., 1997) and usually, the feeding regime starts with green algae, followed by progressively larger foods such as rotifers, artemia, and minced trash fish. A similar species, *E. striatus*, the Nassau grouper has been reared in captivity by Watanabe et al. (1996) with survival rates of 1.17%.

The objective of this study was to examine the egg and early larval stages of laboratory-reared specimens of *Epinephelus guttatus* in order to describe embryonic and larval development. Descriptive accounts were based on developmental series constructed primarily to document morphological ontogeny. The data collected from this study was used in identification of field-collected ichthyoplankton specimens during a natural aggregation-spawning event occurred in La Parguera, Puerto Rico during the year 1997. Notes on larval behavior relating to development and the rearing environment are also described.

MATERIALS AND METHODS

The controlled culture of *E. guttatus* was conducted at the marine facilities of the Department of Marine Sciences, University of Puerto Rico, during the red hind spawning season (January and February), through three successive years 1999-2001. The rearing methodology for marine fishes described by Houde and Taniguchi (1977) and Tucker (1994) was followed for the culture of the red hind. The first two years produced only partial results and led to modifications in the methodology.

Facilities:

Different types of laboratory setups to raise marine fish organisms were prepared before the beginning of the final culturing phase in 2001. Two outdoor roofed cement holding tanks, 2 X 4 X 0.5 m were available to maintain and acclimatize the breeders. Breeders were captured with hook and line well in advance of the spawning season. These tanks had a continuous seawater flow, and contained natural macro algae where the fish could hide, thus minimizing the stress of captivity. Two indoor laboratories were prepared to conduct all stages of the rearing process: hormone ovulation induction, artificial strip-spawning, dry fertilization of the broodstock, maintenance of the breeders, development of eggs and larvae and the rearing of food supply (algae, rotifers and artemia) for all feeding stages. One temperature-controlled room (24˚C – 26 ˚C) was equipped with all the essential tools to perform the first stages of marine algae cultures, hormone ovulation induction, dry fertilization of eggs, and eclosion of rotifers.

A second indoor room, at ambient temperature, was equipped with a rectangular 200-l transparent plastic tank, where the brookstock was maintained in acclimatization and where spawning induction took place. A 390-l cylindrical fiberglass tank with v-shape bottom was used as the main tank for egg and larval rearing. In addition, eight 60-l aquaria were used to stock eggs at low density (3 eggs / l) from different fertilized eggs batches. Two transparent 120-l cylindrical tanks (0.5 m diameter x 1.5 m height) with artificial light maintained the mass algal cultures (*Isocrhysis galvana* and *Nanochloropsis oculata*). Two additional 20-l transparent tanks for the mass culture of rotifers *Brachionus plicatilis* and *Artemia salina* were prepared for the first and second stages of exogenous feeding of fish larvae. To maintain water quality, all tanks were supplied with filtered aeration and seawater treated with UV and filtered with 0.5 цm mechanic filters. Appropriate draining check valves were connected to the larger reservoirs; the 60-l aquaria were drained from the surface or by siphoning. Each tank and aquarium was equipped with max/min thermometers. Although the seawater system was equipped with an inline heater, this was never needed during the rearing project. The seawater came from a coastal intake, therefore the water properties, including temperature (26.2 ºC), where that prevailing in coastal waters. However, the rearing tank water temperature fluctuated close to 27 ºC during daytime.

All tanks, aquaria and laboratory glassware containers were previously cleaned and disinfected with Clorox or non-toxic Alconox and washed with abundant fresh water.

Capture and acclimation:

Nineteen adult red hinds to be used as broodstock were captured on January 8, 2001 in “El Hoyo” near the shelfedge in La Parguera, PR, using hook and line techniques. After capture, fish that were over-inflated from gas bladder expansion were deflated with a hypodermic needle according with the methodology described by Tucker and Woodward (1996). Of these, five subsequently died due to injuries received during the capture or to unexplained exophthalmia developed in the acclimatizing tank. From the remaining 14 animals, five were sacrificed at the beginning of the induction phase, to determine female stage ripeness. The remaining nine animals were maintained in captivity until February 22, when the artificial reproduction stages ended, and the red hind where set free in shallow waters near the coast. From the nine brooders, three females and two males were selected for induction during February 14 to 22, 2001. This coincided with the appropriate natural maturation and spawning period, that occurred on the known spawning grounds in La Parguera for year 2001.

The fish were fed daily with a high protein diet, based on frozen raw squid, frozen tilapia and trash fish, supplemented with 48% protein-formulated dried pellets, prepared from *Macrobrachium rosenbergii* carapaces, cornmeal, soybean meal, cod-liver oil, vitamin-A and a mineral mix. The red hinds learned to feed on pellets but maintained a high preference for raw food.

Culture of Natural Foods:

The micro algae *Isochrysis galvana* and *Nanochloropsis oculata* were progressively cultured in test tubes, Erlenmeyer flasks, 3-liter flasks and 20-liter crystal bottles using F/2 A and B culture medium, and then transferred to a 120-l transparent fiberglass tank using urea culture medium. The algae were used to feed rotifers and fish larvae. The rotifer, *Brachionus plicatilis* (SS-type and S-type), were initially hatched in Petri dishes with 20 ml sterilized seawater at 15 ppt (density 1.0107 g/m^3) and 25 ˚C temperature room. They were fed with microalgae and two drops of “roti-rich” nutrient at 24 h and 48 h and then transferred to 500-ml, later to 2-l Erlenmeyer flasks and finally to a 20-l tank, when they were fed continuously with the cultured algae and roti-rich.

Ovulation induction:

To induce ovulation on gravid red hind 2500 IU ampullae’s of human chorionic gonadotropin hormone (HCG) were used. Females (712, 860 and 1169 g of body weight) were injected twice with HCG at 0 and 24 hours using different doses 450, 650 and 950 IU/Kg of body weight. The two males (896 and 1364 g body weight) received a single dose of HCG 800 IU/g of body weight. Detailed results from these trials were reported by (Quintero et al., 2001).

When under stress, females sometimes retain ovulated eggs until they overripen, (Tucker and Woodward, 1996). To avoid that eggs lose their viability due to over-ripening, careful cannulations were performed to females before and during the induction ovulation period. Over-ripening was found to be the main cause of unsuccessful results during the first two years. Only stripped eggs were used for culture purposes, because they are cleaner and already concentrated. Anesthesia was never necessary when weighing, measuring, processing, injecting or spawning the brood fish. They were handled gently but decisively and without hesitation, using soft nylon nets, and clear polyethylene bags. After the animal was in position its eyes were covered with a wet soft cloth.

Fertilization:

Fertile eggs at favorable ovulation stages were obtained by stripping females at 48 hours after the HCG hormone injection. The mass of eggs was collected in a clean dry beaker; the male milt was collected using a syringe without needle. The mass of eggs was gently mixed with only a few drops of milt, using a clean feather. A few drops of milt are enough to fertilize a million of eggs, while excess milt could reduce water quality due to decomposition.

Seawater at the same temperature of the breeder's tank was added to the beaker followed by gentle agitation. Eggs were then transferred to a larger container, and after several minutes the unviable eggs collapsed and sank to the bottom. These unviable eggs were removed by siphoning, before seeding the eclosion tank and aquaria. One additional flask was seeded inside the controlled temperature room with approximately 50 viable eggs to test the eclosion timing at lower temperatures (24 ºC). Meanwhile the rearing tank and aquaria were maintained with continuous flowing filtered water that ranged between 26.2 ºC and 27 ºC.

Larval feeding and ontogenetic development:

The development of embryos and larvae were constantly monitored during the rearing process. Representative samples of embryos and larvae were collected at 30 minutes, 1, 2, 6, 21, 22, 24, 30, 45, 50, 54, 64, 70 and 82 hours after fertilization, and fixed in 95% of alcohol for their posterior graphic and ontogenetic development description.

External addition of natural food commenced before the larvae completed the absorption of their vitelline sac. Starting on day three, larvae were fed with mixed cultured microalgae (*Isochrysis*, *Nanochloropsis*) and rotifers. To increase rotifer capture effectiveness by larvae, the rotifers were sieved through a 105 um and a 27 um mesh, keeping only the smallest rotifers to ensure fitness to the red hind larval mouth gape-size during their first exogenous feeding.

Live stereoscopic digital photomicrographs were taken of eggs at 6 hours after fertilization and of larvae at 1, 2, 3, 4 and 5 days after fertilization. Descriptions of embryonic development were based on the continuous observations of live eggs, from just after fertilization until the onset of hatching. Descriptive notes were taken daily concerning larval pigmentation, morphological development and behavior. Subsequent samples were taken irregularly and sketches were scanned and cleaned, improving details using a microcomputer paint package.

All morphometric measurements were made to nearest 0.01 mm by means of a binocular dissecting microscope, fitted with an ocular micrometer. The following morphometric measurements were made: eggs diameter (**ED** = spherical diameter of eggs); oil globule diameters (**OIL** = diameter of oil globule measured horizontally); preanal length (**PAL**= tip of snout to posterior edge of anus); total length (**TL** = tip of snout to edge of caudal finfold); body depth (**BD** = greatest vertical distance between body margins) and eye width (**EW** = horizontal length of eye). These data were used to build a morphometrics table and for the estimation of growth rates.

Descriptions of the early stages of ontogenetic development on red hind followed Balon's (1985) life history model. The "saltatory" (stepwise) ontogeny model is a hierarchical system of intervals – periods, phases and steps, which the individual undergoes from activation to death. This model is adjusted to all those sequences of longer "accumulative" steady states, and all other rapid changes in form and function. If all those prolonged accumulations and canalizations of complex structures developing at various rates occur at their due time, it will render the next rapid change possible. The entire ontogeny from beginning to end consists of four to five periods: embryo, larva (often missing or replaced by 'alevin'), juvenile, adult and senescence. The thresholds that separate periods are more distinct than those that separate the shortest saltatory intervals of ontogeny, the steps. The ontogenetic description of early development of red hind will be restricted to only the first two periods, ***embryo period*** and the ***alevin period*** with their corresponding phases and steps.

RESULTS

Ovulation and stripping Fertilization:

All three female red hinds treated with different doses of HCG were induced to ovulate, reaching a stage favorable for the fertilization at 48 hours after the first injection. At this time females had a highly prominent belly, and the urogenital papillae were extruded in females and extended in males (Figure 4). Female behavior became sluggish with noticeable rapid changes in body pattern coloration. Irregular black vertical bands interchanged with pale red body patterns, and there was a rising and turning down the dorsal fin as a peculiar courtship sign. Meanwhile the male became more agitated, turning laterally and making passes underneath the female belly. Along with these underneath lateral passes the male made little punches belly to belly, probably to force the female to begin the spawning rituals. No females spawned voluntarily. Therefore, gamete stripping and dry fertilization were conducted as described.

Red hind - Female   Red hind – male

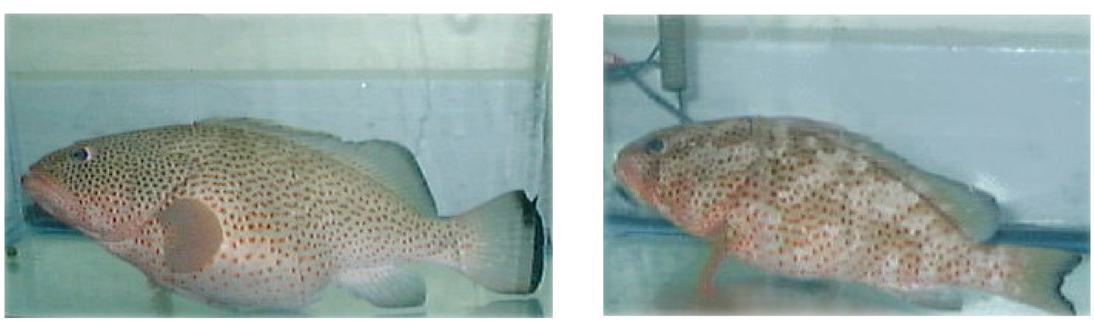


Figure 4. Ripe red hind female and male 48 hr after of hormone injections to induce spawning.

Egg and embryonic development:

Live unfertilized (recently spawned) red hind eggs, are positively buoyant only for a few minutes (Figure 5A). They are transparent, and generally have a single yellowish oil globule just below the chorion surface. Those activated by fertilization maintained positive buoyancy in seawater throughout the incubation period, staying near the air-water interface film. Unfertilized and unviable eggs loose their buoyancy, gradually deteriorating and changing their transparency to an opaque view.

Red hind eggs are **telolecithic** (large vitelum concentrated at one side of the egg) and display typical **meroblastic** cleavage (partial segmentation of the egg). During active division, the cytoplasm is confined to a discoidal mass over the vitellum. The yolk was unsegmented, and at early stages the eggs lacked pigmentation.

Table 1 summarizes the saltatory ontogenetic development model (Balon, 1985), applied to the red hind (*Epinephelus guttatus*). The first two periods (embryo and alevin) will be described in detail, from results obtained through laboratory rearing.

<u>The embryonic period:</u>

The first period in the life history of oviparous fishes starts with egg activation at the time of spawning and ends when the young begin to feed externally. In red hind, the embryonic period ended with the beginning of an interval of mixed (endogenous + exogenous) nutrition at age 70 hr. At 26.2 °C – 27 ºC the *cleavage phase* lasted for 3 to 4 hr, *the embryo* phase within 22 to 24 hr when hatching occurred, and the *free embryo phase* began at age 70 hr when exogenous feeding apparently started.

Table 1. The saltatory development model (Balon, 1985), applied to the *E. guttatus.*

Embryo period	
The cleavage phase	
Step $C^1 1$	Formation of the perivitelline space and bipolar differentiation (formation of the blastodisc).
Step $C^2 2$	First multiplication of cells, cleavage, and the formation of a morula.
Step $C^3 3$	Gastrula, the beginning of epiboly, the formation of the germ ring and embryonic shield.
The embryo phase	
Step $E^1 4$	Closure of the germ ring: brain optic and auditory vesicle formation; separation of the tail end.
Step $E^2 5$	The beginning of the trunk movement, heart beats, and the circulation enlarge, appearance of first melanophores.
Step $E^3 6$	Rapid expansion of the respiratory yolk plexus of subintestinal, and mixed hepatic descent.
Step $E^4 7$	Function of the hepatic-vitelline and caudal respiratory plexuses, rapid expansion of pigment at hatching.
The free embryo phase	
Step $F^1 8$	Differentiation of the embryonic finfold, formation of first dermal rays in unpaired fins, development of first chondrified skeletal structures and growth of pelvic fins beyond the finfold edge.
Step $F^2 9$	Transfer to mainly branchial respiration and calcification of jaw tooth points, complete absorption of the yolk. Termination of surface suspension.
Alevin Period	
Step $A^1 10$	Mixed, endogenous and exogenous feeding; formation of the gas bladder; development of eye pigmentation, and melanine patches laterally and over the gut region; separation of all unpaired fins, disappearance of remnants of preanal embryonic finfold.
Step $A^2 11$	Swimbladder fill, calcification of axial skeleton, efficient exogenous feeding, rapid growth, increase in depth and pigmentation, beginning of the urostyle flexion.
Juvenile Period	
Adult Period	
Senescence Period	

-The cleavage phase:

The chorion of the egg was permeable for spermatozoa only through a small funnel, the micropyle, at the animal pole. The micropyle closed after the entry of a single sperm.

Pelagic fertilized eggs of the red hind were spherical in shape with a diameter measuring **ED** = 0.95 mm (± 0.03 S.D., n = 30). Each possessed a single oil globule **OIL** = 0.24 mm (± 0.01 S.D., n = 30) in diameter. All live fertilized eggs were transparent with a smooth chorion and a thin perivitelline space (Figure 5B & C).

* **Step $C^1$1.** *Formation of the perivitelline space and the blastodisc*

A continuous perivitelline space develops after fertilization, between and after the detachment of the chorion and the vitelline membrane (Figure 5B & C). Although an increase in egg volume occurs, the perivitelline space does not contribute to the buoyancy of the egg (Hempel, G., 1979), because it is filled with water drawn from outside the egg through an osmotic equilibrium process. Polar differentiation was indicated by a brownish colored blastodisc, and the yolk upper the blastodisc was irregularly flattened (Figure 5B & C).

* **Step $C^2$2.** *Cleavage of the Blastodisc*

During this step the blastodisc went through the process of cleavage, which lasted 6 to 7 hr, forming the morula and ended before the beginning of the epiboly. The earliest indication of cleavage was an increase in cytoplasm density along the plane of the first cleavage furrow. The process started about 1 hr after fertilization with the first blastomere division (Figure 5D & E). At 2 hr the 16 blastomeres stage, with unequal sizes of blastomeres was observed, measuring 0.73 mm in length and 0.5 mm wide (Figure 5F), and at 6 to 7 hr the formation of the morula was completed and the appearance of the germ ring and embryonic shield was ready to form, ending this $\mathbf{C^22}$ Step (Figure 6A).

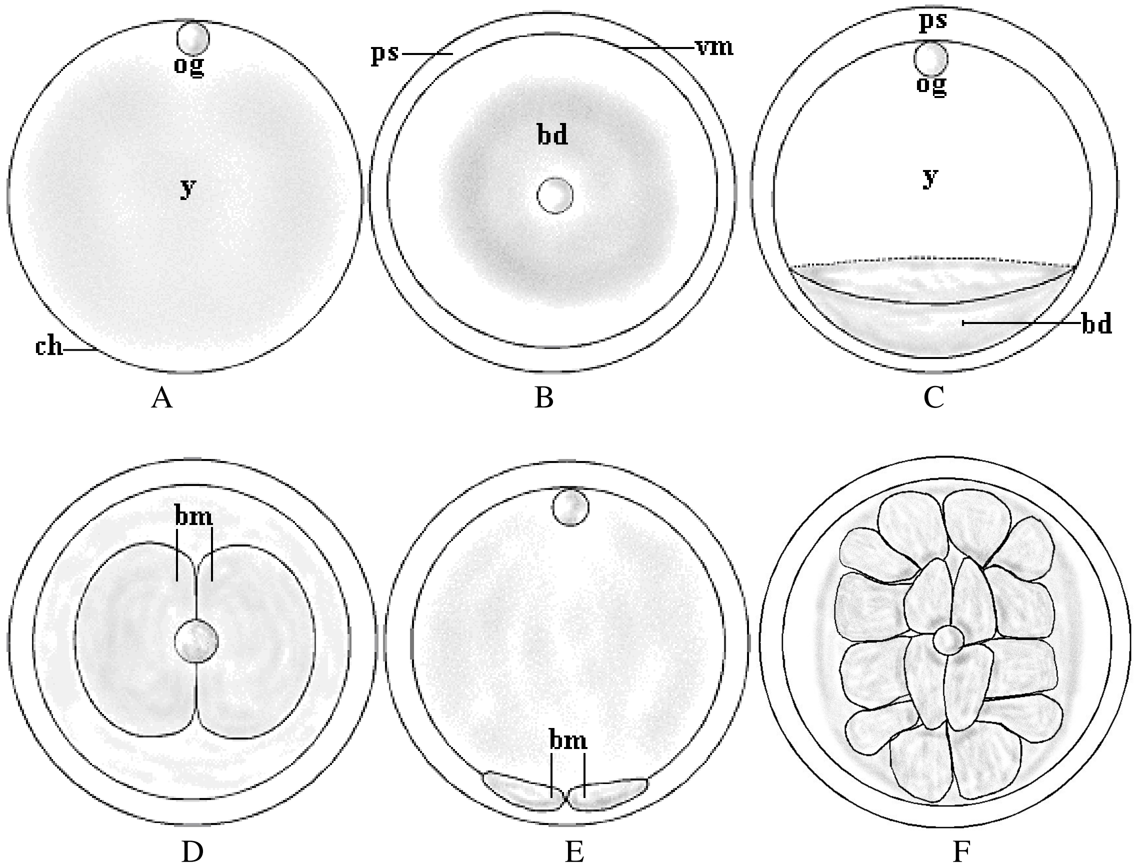


Figure 5. - Early ontogeny development of *Epiniphelus guttatus* A) Unfertilized egg; B) and C) $\mathbf{C^11}$ stage, horizontal and lateral view 30 min after fertilization (Formation of the perivitelline space and the blastodermal cap at the animal pole, the oil globule is located at the vegetative pole); $\mathbf{C^22}$ stage: D) and E) Horizontal and lateral view of the first blastomere division 1 hr after fertilization; f) Cleavage stage at 2 hr after fertilization (16 blastomere stage). **og**-oil globule, **ch**-chorion, **y**-yolk, **ps**-perivitelline space, **bd**-blastodisc, **vm**-vitelline membrane, and **bm**-blastomer.

* **Step $C^3$3.** *Epiboly and Gastrulation*

Individual variations in the timing of development were evident by the first cleavage. Eggs with different numbers of blastomeres or stage of development could be found at any single time i.e., eggs drawn in Figure 6A, B, & C were collected 6 hr after fertilization, with 6B & C showing a germ ring and embryonic shield in an advanced gastrulation and epiboly, a clear **$C^3$3** stage, while in 6A, a **$C^2$2** stage, this development could not be observed, only an advanced morula.

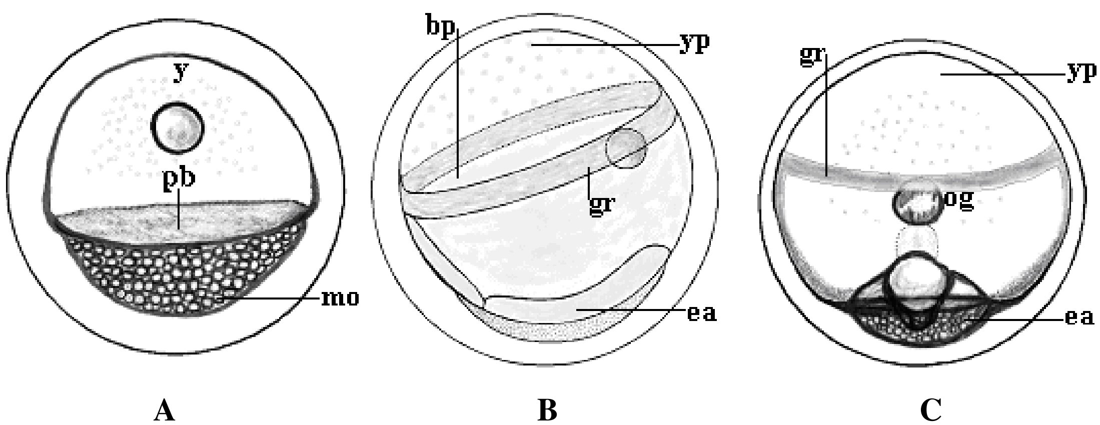


Figure 6. Eggs of *Epinephelus guttatus* A) morula stage (6 hr after fertilization), at end of step **$C^2$2** and beginning of **$C^3$3**; B and C). In middle of Epiboly and Gastrulation step **$C^3$3**, lateral and frontal views (6 hr after fertilization). **y**-yolk, **pb**-periblast, **bp**-blastopore , **mo**-morula, **yp**-yolk plug, **ea**-embryonic axis, **gr**-germinal ring, **og**-oil globule.

The last stage of the cleavage phase **$C^3$3** started with the epiboly at 6 to 7 hr and ended with the onset of the organogenesis at 21 hr after fertilization. Epiboly was indicated by several changes in blastodisc morphology, (Figures 6B & C). The width of the blastodisc at the margin and the distance between the margin and the apex both increased. The blastodisc no longer sat atop the yolk but rather had thinned and was wrapped around it. A cellular mass projected over the yolk surface interrupting the circular symmetry of the blastodisc margin (Figures 6b & c). The germ ring and embryonic shield were evident as thicker areas, the embryonic shield was located at the blastoderm disc and the germ ring advanced over the yolk at 6 to 7 hours after fertilization (Figures 6B & C).

By 21 hr the germ ring had almost completed wrapping around the yolk and continued until full enclosure, the oil globule was located under the tail of the embryo, slight constrictions in the embryo brain area appeared, optic vesicles developed and more than 20 somites were visible. The trunk-tail mound, which enveloped the oil globule, was dorso-ventrally flattened (Figure 7A). Further lateral compression of the embryonic shield produced a more definitive axial body form. One embryo was measured, having a **TL** = 1.2 mm, **OIL** = 0.23 mm and **EW** = 0.1 mm.

- The embryonic phase:

This phase of ontogeny began after the closure of the germ ring at 22 hr after fertilization, followed by the organogenesis. At this time the embryo underwent an intense morphogenesis in a short period of time (approximately two hours), ending this phase at age 24 hr when hatching occurred.

* Steps **$E^1$4 and $E^2$5:** The samples collected at age 22 hr showed mixed Steps **$E^1$4** and **$E^2$5** characters. From the first step the germ ring was finally closed, the brain and the optic and the auditory vesicles were formed, and the tail was separated at the end. From the $E^2$5 Step, the beginning of trunk movements, the heart beat and the presence of lenses in the optic cups were evident. A continuous dorsal and ventral finfold was formed, and 24 somites were well delimited (Figure 7B). Curiously some of these characteristics were observed

preceding the final closure of the germ ring (Figure 7A), as were the formation of the optic vesicles and formation of the brain, but the tail-end was not separated.

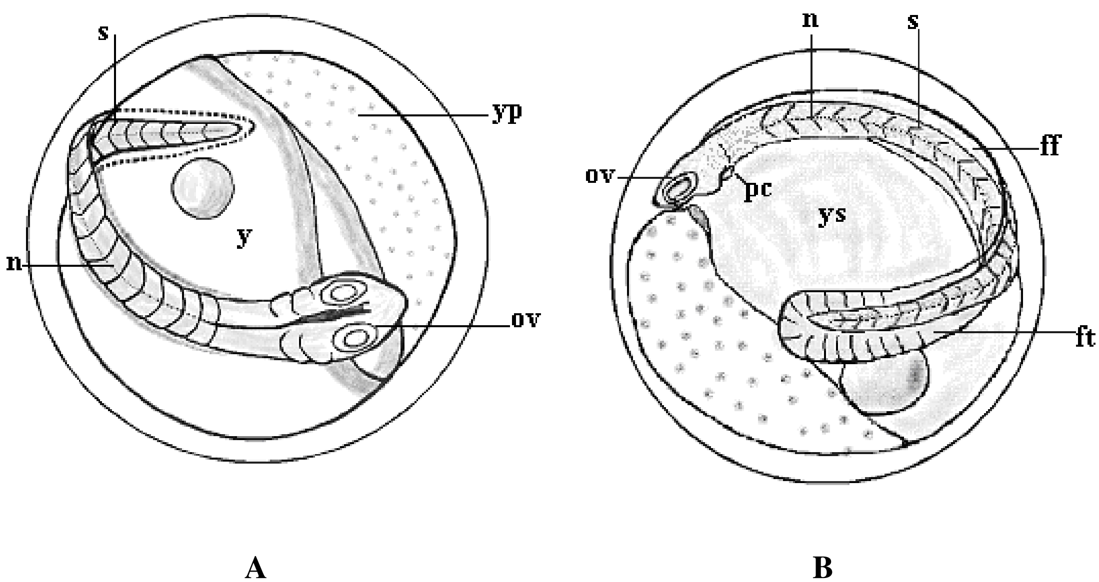


Figure 7. Eggs of *Epinephelus guttatus* in transition from the cleavage to embryonic phases. A) Advanced stage of Epiboly $\mathbf{C^{3}3}$ (at 21 hr after fertilization), and B) Embryonic phase Step $\mathbf{E^{1}4}$—$\mathbf{E^{2}5}$, at 22 hr after fertilization. **s**-somites, **n**-notochord, **yp**-yolk plug, **ov**-ocular vesicle, **pc**-pericard, **ys**-yolk sac, **ff**-finfold and **ft**-free tail.

* Steps $\mathbf{E^{3}6}$ and $\mathbf{E^{4}7}$**:** Due to the rapid rate of development during the embryonic phase these two Steps occurred during the interval spanning 22-24 hr after fertilization. When sampled at 24 hr, the specimens collected had already hatched (Figure 8). According to the development model, the following should have occurred: Step $\mathbf{E^{3}6}$**-** rapid expansion of the respiratory yolk plexus of subintestinal and mixed hepatic descent; and step $\mathbf{E^{4}7}$**-** function of the hepatic-vitelline and caudal respiratory plexuses, rapid expansion of pigments and hatching.

Recently hatched larvae were collected 24 hr after fertilization. Thus, the eclosion at 26.2 ˚C occurred between 23 to 24 hours after fertilization.

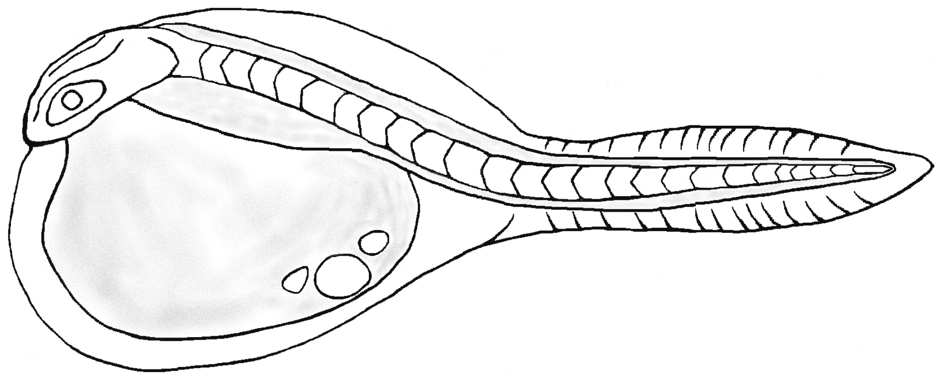


Figure 8. Red hind free embryo just after hatching, **TL**=1.54 mm (± 0.13 SD), 24 hr after fertilization.

- The free embryo (eleutheroembryonic) phase:

By definition, the eleutherombryonic phase refers to the interval during which the young fish exists beyond the confines of the egg membranes while still feeding on the yolk. The eleutheroembryo phase lasted until approximately 70 hr after fertilization when mixed, endogenous and external feeding apparently began.

*** Step $F^1$8:** This is characterized by surface suspension, reduced vitelline circulation, pectoral fins moving, mouth open, blood circulation to the gills, and rapid increase in total length, (Figures 8, 9 and 10).

Just hatched larvae (Figure 8) remained in motionless suspension immediately below the water surface in an upside-down orientation. In this manner the eleutheroembryo would be in an environment of maximal oxygen concentration with a minimal expenditure of energy, and transported by surface currents under natural conditions. After hatching, the embryo measured **TL** = 1.54 mm (± 0.13 SD, n=6), and had no eye pigmentation. One oil droplet and two additional vacuoles were observed at this stage in a ventral posterior position of the yolk sac. The oil droplet [**OIL** = 0.21 (± 0.01 SD, n=6)] was bigger than the two vacuoles. Twenty-four well-differentiated vertebrae could be observed at this time, but the rectal enlarge and anus opening were not present until 30 hr after fertilization (Figure 9). Disperse eye and cranial pigmentations appeared at 30 hr after hatching, with the embryo measuring **TL** = 1.91 mm (± 0.06 SD, n=6). At this time movement consisted only of infrequent body bursts, still in an upside-down position. Following any change in vertical position in the water column the embryo would remain still and slowly returned to the surface by positive buoyancy.

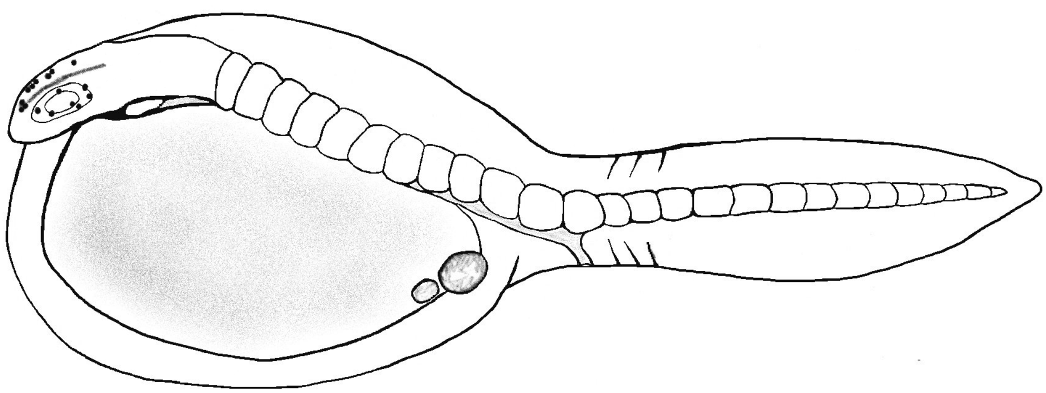


Figure 9. Red hind free embryo, **TL** = 1.13 mm (± 0.03 SD), 30 hr after of fertilization.

At age 45 hr after fertilization (Figure 10), the embryo had small melanophore patches in front of the eye and three radiated melanin concentrations in the anterior position of the yolk sac. The auditory vesicles, vertebrae, and occipital region were well defined and the embryo initiated differentiation of the mouth opening. The oil droplet was posteriorly positioned in the yolk sac and the primordial intestine vein could be distinguished. Unpigmented eyes measured **EW** = 0.23 mm. The preanal length was **PAL** = 1.16 mm, and Total length **TL** = 2.4 mm, body depth **BD** = 0.66 mm and the oil droplet measured **OIL** = 0.17 mm. Both, the dorsal and ventral finfolds were more elaborated with higher surface area. At this time the larvae swam slightly more actively, but not continuously. They could change and sustain their vertical position in the rearing tank, generally swimming in vertical position. This behavior allows the larvae to swim up or down without the markedly positive buoyancy showed in the previous sample. A considerable amount of yolk sac is still available, and the differentiation of the digestive structures continued.

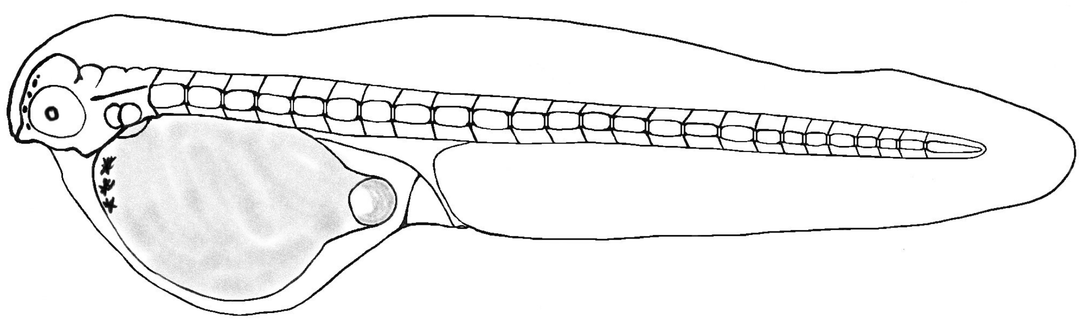


Figure 10. Red hind free embryo, **TL** = 2.28 mm (±0.10 SD), 45 hr after fertilization.

* **Step $F^2$9**: Transfer to gill respiration, termination of surface suspension, increase in active swimming, rapid yolk sac depletion.

At 50 hr after fertilization (Figure 11) a definitive termination of surface suspension was observed, the embryo continued mouth opening differentiation and the beginning of the opercular area with the cleithrum had its first visible definition. The finfold maintained a continuous form in the caudal region, and a more elaborated neural definition could be observed connecting the cerebellum to the neural cord axis. The oil droplet, measuring **OIL** = 0.17 mm, maintained the posterior position on the yolk sac, and the organization of the digestive area was more elaborated, probably towards the development of the liver, stomach and intestine primordials. The Plate 1A shows a photomicrograph of the 50 hr larva stage. Only three embryos were measured at this time, having a **TL** = 2.28 mm (± 0.05 SD, n=3), **PAL** = 1.11 mm (± 0.07 SD, n=3), **EW** = 0.2 mm and **BW** = 0.53 mm (± 0.03 SD, n=3).

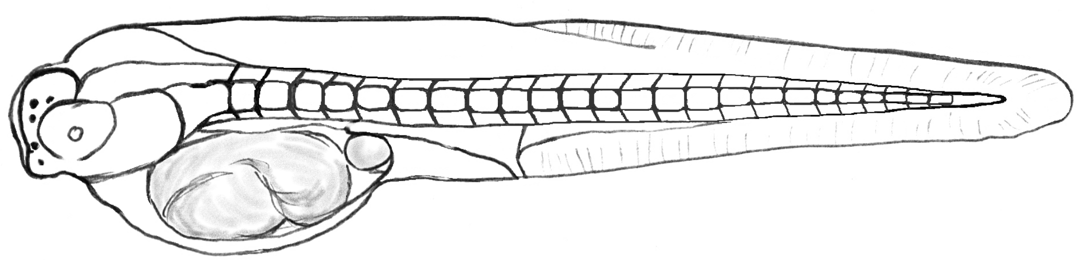


Figure 11. Red hind free embryo **TL** = 2.28 mm (± 0.05 SD), at 50 hr after fertilization.

The characteristics that most stand out 54 hr after fertilization (Figure 12) are: that the yolk sack was vestigial and the oil globule had been reduced to about half of its original size; the whole surface of the body was covered by tiny circular vesicles that were perceptible under reflected light; the dorsal and anal finfolds had narrowed in the peduncle region, and the caudal finfold had broadened; the embryos moved more vigorously; the mouth was much more defined but not functional; rudimentary pectoral fin buds were present and, veins entering the gills gave an appearance of a connection between the yolk sac and the oral cavity. The measurements were: **OIL** = 0.17 mm, **PAL** = 1.21 mm (± 0.03 SD, n=4), **TL** = 2.39 mm (± 0.11 SD, n=4), **BW** = 0.67 mm (± 0.03 SD, n=4) and **EW** = 0.20 mm.

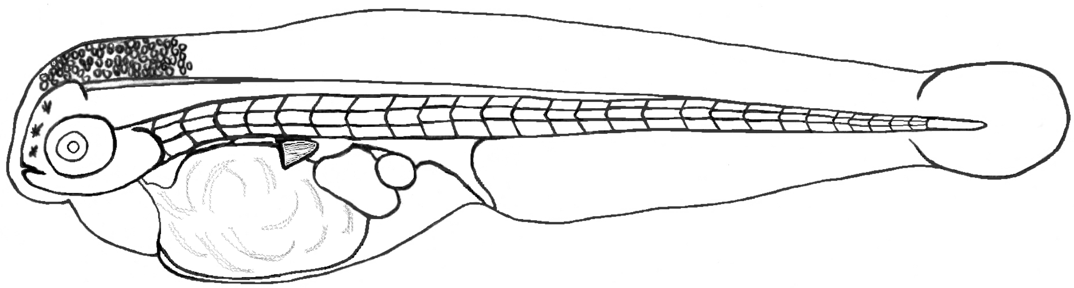


Figure 12. Red hind embryo at age 54 hours after fertilization. Dermal vesicles covering the entire body are partially presented for the occipital region only.

At 64 hr after fertilization (Figure 13) the embryo mouth was almost functional. The cleithrum was formed and the opercular opening was visible. Although formation of the gill arches could not be followed without special staining techniques, the opercular-cleithrum definition characterizes the onset on branquial respiration. Opercular movement on live specimens could be observed under dissecting microscope. The embryo developed two protuberant bulbous knobs in the anterior region in front of the eye but not extruded through the epidermis; these were probably related to the olfactory sensory system. The pectoral fins had increased in size and form. The caudal region remained unchanged compared to the preceding sample. The oil globule was absent in all but one specimen. Some vitelline material remained in the yolk sac, thus indicating the imminent and necessary change to exogenous feeding. At this time the stomach was formed, but the presence of exogenous food could not be observed. From the four specimens measured at this age, only one had a negligible 0.07 mm oil globule and was not tabulated to mean measurement values. The meristics obtained were: **EW** = 0.21 mm (± 0.02 SD, n=4), **TL** = 2.41 mm (± 0.07 SD, n=4), **PAL** = 1.21 mm (± 0.08 SD, n+4) and **BW** = 0.68 mm (± 0.02 SD, n=4).

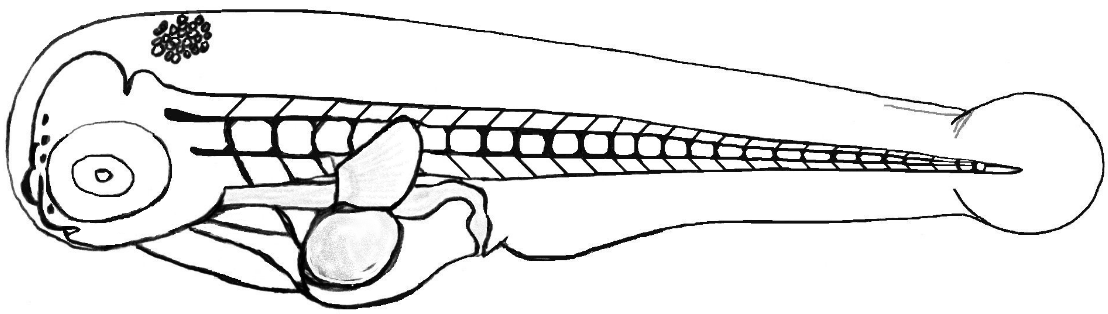


Figure 13. Red hind free embryo, **TL** = 2.41 mm (± 0.07 SD) at 64 hr after fertilization. Dermal vesicles covering the entire body are partially presented for the occipital region only.

<u>*The larval period:*</u>

The larval period began with the onset of exogenous feeding, after what the larva should undergo the disappearance of remnants of the preanal embryonic finfold, separation and final formation of the unpaired fins, efficient exogenous feeding, filling of the swimbladder, rapid growth, increase in depth and pigmentation, and ends with the complete calcification of the axial skeleton. At the end of the period the larva is in a competent status to undergo further settlement and metamorphosis to the juvenile period.

This period was partially observed during its initial stages only. For unexplained reasons the larvae didn't survive long enough to see the separation of the unpaired fins, the filling of the swim bladder, the complete calcification of the axial skeleton nor a rapid growth after the onset of the exogenous feeding.

Step A[1]10: Mixed exogenous and endogenous feeding, separation of all unpaired fins, and the disappearance of remnants of preanal embryonic finfold.

At 70 hr after fertilization the oil globule was completely depleted and the residual yolk was in the final stage of consumption, larvae had pigmented irregular eyes, choroids with an anterior-ventral fissure, the mouth was completely functional, and the digestive system was fully differentiated. The body was completely covered by dermal vesicles. In the schematization as seen in Figure 14, we show only partially this pattern. The pectoral fins were well developed, but the dorsal and anal finfold showed no additional separation. The Plate 1B shows a photomicrograph of the 70 hr larva stage.

Scattered radiated melanine pigments formed in the upper and lateral region of the convoluted intestine region. The larvae at this time swam freely in the water column and were found more frequently at the edges of the rearing tank, near the surface and probably seeking food. The mean measurements were **EW** = 0.23 mm, **TL** = 2.48 mm (± 0.14 SD, n=4), **PAL** = 1.22 mm (± 0.04 SD, n=4) and **BW** = 0.68 mm (± 0.02 SD, n=4).

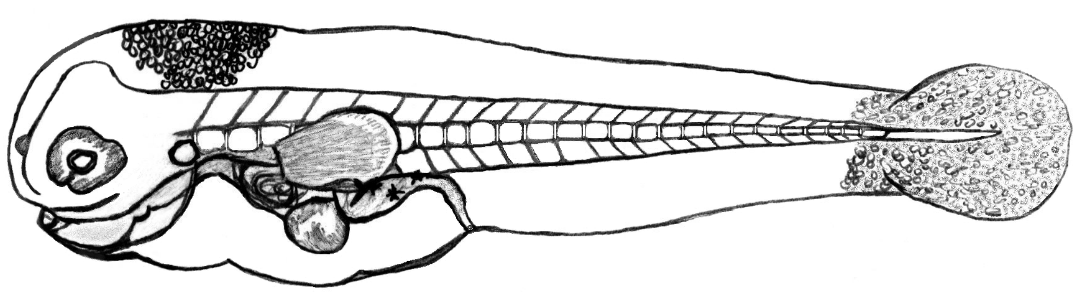


Figure 14. Red hind larva, **TL** = 2.48 mm (± 0.14 SD) at 70 hr after fertilization. Dermal vesicles covering the entire body are partially presented for the occipital region only.

At 82 hr after fertilization (Figure 15) the larvae had highly pigmented eyes, and the mandible and maxillary bones were completely differentiated, probably having some degree of calcification. The axial skeleton and caudal region showed development compared to the preceding sampling. Pigmentation over the gut formed a dense elongated patch. The digestive system occupies more volume, and a little space over the gut could be related to the initiation of the gas bladder formation. No signs of flexion of the urostyle could be observed at this last sample from the rearing experiment. The measurements at 82 hr after fertilization were obtained from only one specimen, having **EW** = 0.24 mm, **TL** = 2.91 mm, **PAL** = 1.40 mm and **BW** = 0.7 mm. Although the individuals examined at 70 and at 82 hr after fertilization did not show a clear presence of food particles in their guts, the food seeking behavior, the oil globule depletion and final yolk consumption, the full development of the digestive system, and the increase in growth rate observed at 82 hr, suggests that larvae had been exogenously feeding, at least on smaller phytoplankton particles.

To finish the ontogenetic development illustration series of the red hind, I followed the illustrations presented by Richards (1994), where three red hind post-flexion larvae having 6.0 mm, 8.4 mm and 33 mm of standard length, were available, (Figure 16). The Plate 2A, B and C show photomicrographs at 82 hr after fertilization and their associated structures.

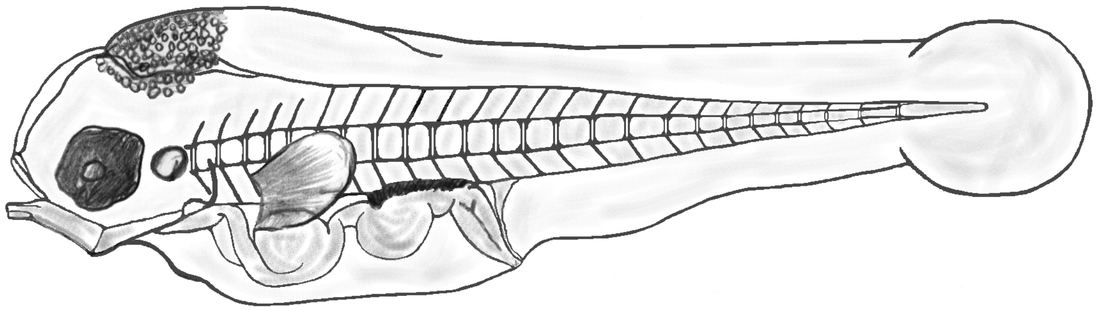


Figure 15. Red hind larva, **TL** = 2.91 mm, at 82 hr after fertilization. Dermal vesicles covering the entire body are partially presented for the occipital region only.

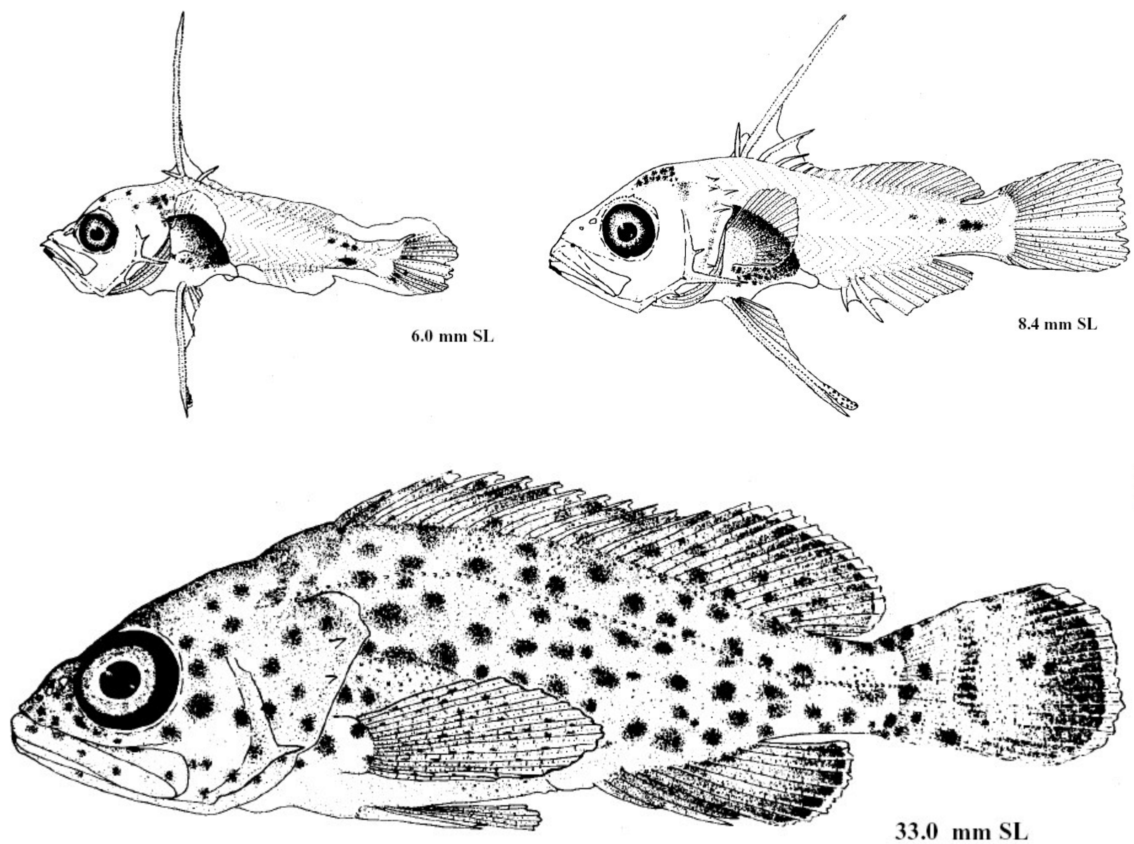
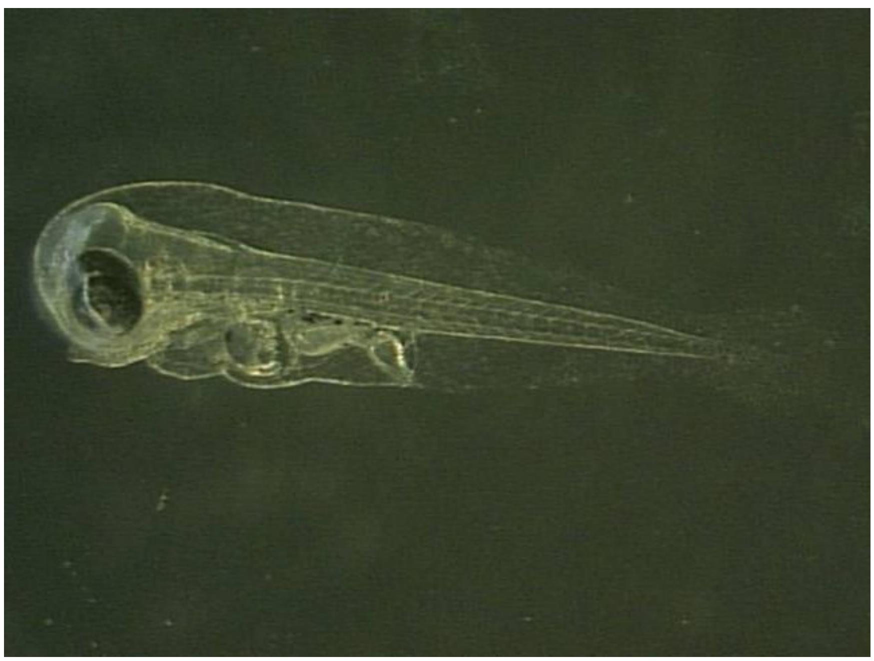


Figure 16. Postflexion larvae illustrations of red hind from (Richards, 1994).

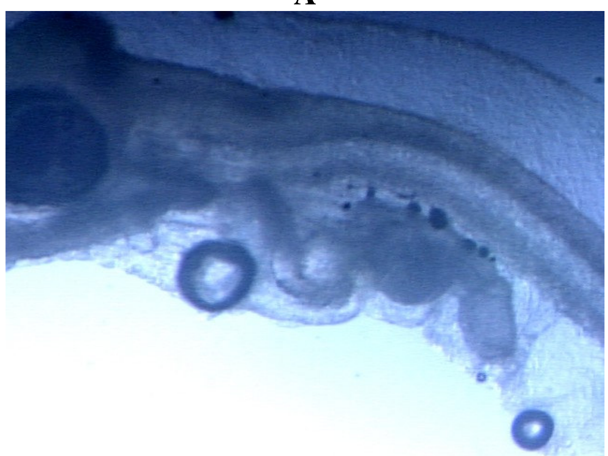
A – 50 hr



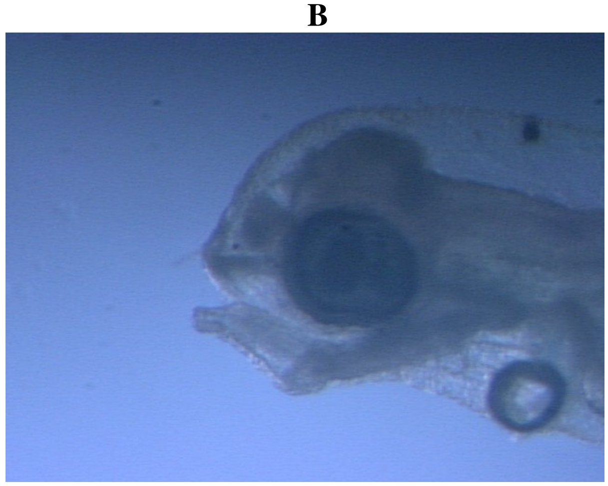
B – 70 hr

Plate 1. Photomicrographs of *E. guttatus* larvae, A) at 50 after fertilization and B) 70 hr after fertilization.

A



B



C

Plate 2. *E*. Photomicrographs of *E. guttatus* larvae at 82 hours after fertilization, A) larva B) Enlargements of the digestive system and C) enlargement of oral area.

DISCUSSION

In this study, eggs and early (pre-flexion) larvae of *Epinephelus guttatus* are described and illustrated for the first time. Previous works describing early life history of Serranids are few, in comparison to the abundance and importance of this group. Epinepheline larvae seem to be underrepresented in plankton hauls, and published results are often given in terms of family Serranidae as a whole, therefore making information on epinephelines inaccessible, (Leis, 1984).

The average egg of *E. guttatus* obtained by HCG hormone induction in our study had a diameter of 0.95 mm (range 0.9 – 1.0) and a single 0.24 mm (0.21 – 0.26) oil globule. Present results are similar to those of Tucker (1994) (0.944 mm diameter) in Bermuda using the same method, and with those of Colin et al. (1987), (0.96-0.97 mm) for *E. guttatus* and of Powell and Tucker (1992) for *E. striatus* (0.92 mm).

Development in the red hind showed a very close similarity with other Epinephelinae species, as exemplified by the early stages (pre-flexion) of *E. morio* (Richards, 1994). When compared, the sizes and morphology were very close among the two species. Such similarity makes it difficult, if not impossible, to distinguish epinephelinae larvae to species level. These similarities suggest that other subfamily species, still undescribed, will share the same early ontogenetic development stages characteristics, before species-specific characters develop.

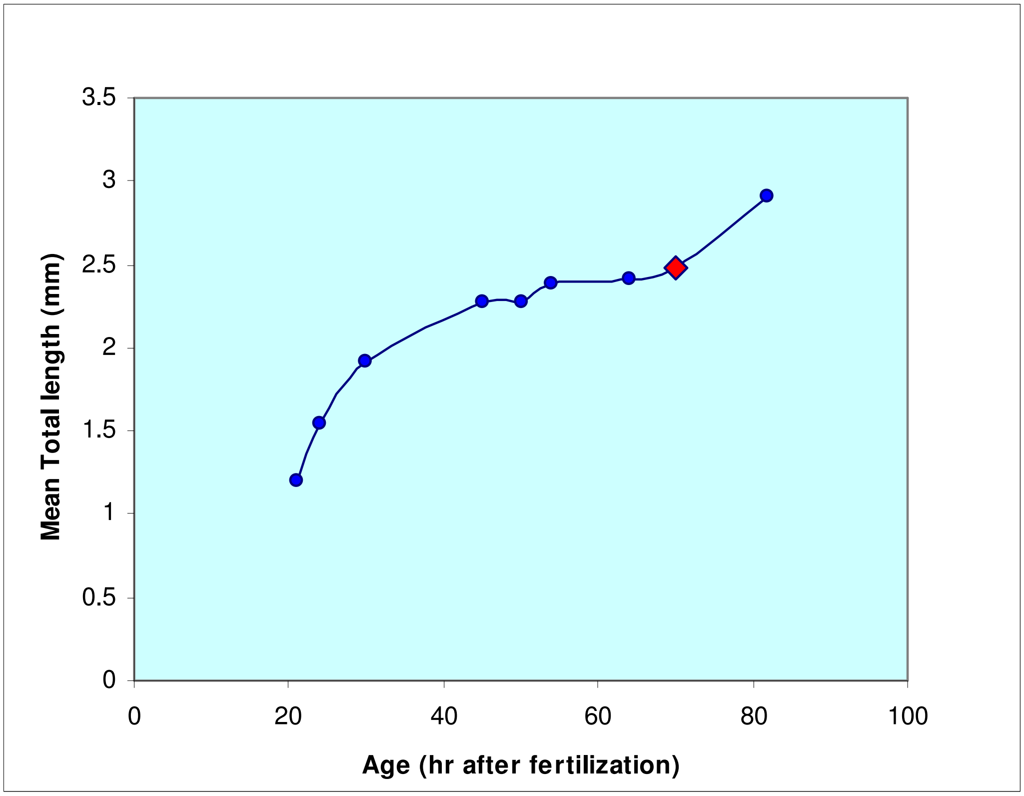
The ontogenetic development described in this study for *Epinephelus guttatus* should be strongly related to the water temperature, which in these rearing trials ranged from 26.2 ºC to near 27 ºC. It is known that for many marine and freshwater fishes the temperature range in which spawning occurs is rather narrow (Hempel, 1979), and hatching and survival is maximized at specific temperatures. Temperature will affect the relative timing of growth, differentiation, yolk consumption, overall development stage, and when exogenous feeding will take place. Elsewhere in the study (Chapter 3) It is argued that red hind in Puerto Rico are adapted to reproduce in nature at water temperatures ranging 25.5 ºC to 26 ºC. Thus, the temperature difference between the rearing trials and the natural environment could affect the timing of yolk consumption and the onset of exogenous feeding in our study. For example, 50 eggs incubated inside the temperature controlled room (24˚C) lasted six hr longer (Total=30 hr) than larvae in the rearing tank, and the development stages and growth rate were delayed in comparison to those incubated at 26.2 ºC - 27 ºC.

Table 2 summarizes all morphometrics obtained during the early ontogenetic development of the *E. guttatus*, in this study. The most notable result was the variation in growth rate. Growth was rapid from hatching until 45 hr after fertilization, and then it slowed substantially between 45 hr and 70 hr (Figure 17). It is well known that temperature affects the growth rate, the efficiency of yolk rate utilization, synchronization and differentiation of internal organs and the development of white muscle. But the final outcome of all the temperature-dependent features can also be expressed in terms of the survival time on the yolk reserve (Blaxter, 1992), where the larvae can reach the point of no return (defined as the point at which the larva has exhausted all its yolk reserves, is still alive, but is just to weak to feed if an exogenous food supply becomes available). If the red hind has a narrow range of temperature for a healthy and synchronized development, then the higher than natural temperatures used during rearing could explain the high mortality that occurred. Starvation was probably the main factor affecting survival during the onset to exogenous feeding. However, the larvae at 82 hours after fertilization showed a marked increase in growth rate, which may indicate they were able to initiate feeding from exogenous supplies, or that this rapid growth occurred at the expense of the last food reserves, which resulted in subsequent starvation.

Table 2: Summary of mean morphometric measures (mm) ± S.D. of early development stages of *E. guttatus.* Reared at 26.2-27˚C. **ED** = egg diameter, **OIL** = oil globule diameter, **EW** = eye width, **TL** = total length, **BW** = body width and **n** = number of specimens measured, **Age** is hr after fertilization.

Age	ED	OIL	EW	TL	PAL	BW	n
0.5 hr	0.95 ± 0.03	0.24 ± 0.01	*****	*****	*****	*****	n=30
21 h	0.95	0.23	0.10	1.20	*****	*****	n=1
24 h	*****	0.21 ± 0.01	0.12 ± 0.02	1.54 ± 0.13	*****	0.67 ± 0.01	n=6
30 h	*****	0.18 ± 0.02	0.21 ± 0.02	1.91 ± 0.06	1.07 ± 0.06	0.74 ± 0.07	n=6
45 h	*****	0.17 ± 0.00	0.21 ± 0.02	2.28 ± 0.10	1.13 ± 0.03	0.68 ± 0.02	n=4
50 h	*****	0.17 ± 0.0	0.20 ± 0.00	2.28 ± 0.05	1.11 ± 0.07	0.53 ± 0.03	n=3
54 h	*****	0.17 ± 0.0	0.20 ± 0.00	2.39 ± 0.11	1.21 ± 0.03	0.67 ± 0.03	n=4
64 h	*****	*****	0.21 ± 0.02	2.41 ± 0.07	1.21 ± 0.08	0.68 ± 0.02	n=4
70 h	*****	*****	0.23 ± 0.00	2.48 ± 0.14	1.22 ± 0.04	0.68 ± 0.02	n=4
82 h	*****	*****	0.24	2.91	1.40	0.70	n=1

Figure 17: Age and mean total length in early development stages (21 to 82 hours after fertilization) of *Epinephelus guttatus*. The symbol in red represents the apparent onset of exogenous feeding.



The period defined as Step $F^2 9$ (end of the free embryo phase, between 45 to 70 hr after fertilization), was the stage characterized by a low **TL** growth rate. This developmental interval is related to the embryo's preparation for the onset of exogenous feeding, after which an ontogenetic saltatory process should occur. The larva that survived this period was characterized by an increase in growth rate (Figure 17). This period of slow growth is similar to that obtained for the snapper *Lutjanus synagris* by Borrero et al. (1978) in Cuba, under laboratory rearing conditions. However, they did not feed the fish, which resulted in starvation, a negative growth rate and ultimately death. Riley et al. (1995)

working with another snapper (*Ocyurus chrysurs*) found a positive growth rate at onset of exogenous feeding, similar to the present results.

It is during this critical saltatory transition when mortality due to starvation is thought to be at its highest. Fish larvae are generally visual predators and when small, can only search a relatively small volume of water; thus to get through this critical transition interval, larvae must generally encounter dense concentrations of appropriately sized prey (Humphries et al., 1999), and have their mouth, digestive, and feeding structures well developed. The disparity between most laboratory estimates of food densities required by larvae, and densities observed in the open sea has led to the hypothesis that larvae may be dependent on small-scale patchiness of food (Hunter, 1981). Lasker (1975) tested the patchiness hypothesis by exposing larvae to samples of water taken from surface and from the chlorophyll maximum layers, usually 15-30 m below the surface. Feeding by larvae was minimal in samples taken from surface, but extensive in water from the chlorophyll maximum layer. Therefore, the temporal maximum of chlorophyll-a concentrations found near the shelfedge around the second full moon of the year (discussed in next chapter), suggests that enhanced patchiness and sufficient conditions of food availability for fish larvae development were present during the 1997 red hind reproduction season off La Parguera.

CHAPTER III

SPATIAL AND TEMPORAL ICHTHYOPLANKTON DISTRIBUTIONS SURRAUNDING A SPAWNING AGGREGATION EVENT

INTRODUCTION

Most coral reef fishes have a dispersive pelagic larval stage that develops from either planktonic or demersal eggs (Leis, 1991), resulting in two distinct and very different life history phases. These pelagic and benthic stages differ in almost all characteristics, from morphology to size, habitat, food and behavior. Duration of the pelagic stage varies considerably among species, from weeks to months (Victor, 1986; Thresher et al., 1989), and species differ in their morphological and physiological adaptations for planktonic life.

Reef fish are known to be highly fecund, with annual egg production ranging from 10,000 to over 1,000,000 eggs (Leis, 1991). However, this reproductive strategy is generally coupled to mortality approaching 100%, the majority of which take place during the pelagic phase (Doherty, 1981). The size of adult populations could be determined, if not influenced, by this pelagic phase (Doherty, 1983). To appropriately manage populations subjected to recruitment variability, the ecology of the pelagic ontogenetic development phases should be understood. The large variations in recruitment that occur in nature could be related to a strong dependency on self seeding from autochthonous spawners, or may depend on larvae imported from other localities (Roberts, 1997).

Offshore larval dispersal has been proposed as a selective strategy to minimize predation on eggs and larvae (Johannes, 1978), maximize the dispersal from natal reefs (Barlow, 1981) or increase the survival of larvae in those areas where food aggregation occurs (Doherty et al., 1985). Thus, spawning generally occurs in places and at times where rapid offshore transport can occur (Shapiro et al., 1988). Leis (1982), Richards (1984) and Victor (1987) reported distributions of reef fish larvae hundreds of miles from the coast. These observations suggested that reef fishes live mainly in open populations (Sale, 1970, 1980; Doherty, 1991). Based on surface current patterns that were used to map potential larval dispersal routes, Roberts (1997) implied that management in the northern Caribbean should be conducted on a regional basis, using networks of interdependent marine reserves. However, a growing number of studies indicate that pelagic larvae are capable of recruiting back to their source population (Emery, 1972; Johannes, 1978; Lobel, 1978; Williams and Andrews, 1984; Jahn and Lavenberg, 1986; Leis, 1986; Lobel and Robinson, 1988; Lee et al., 1992, 1994 and Leis, 1994). More recently, several researchers indicated that local retention may be considerably more prevalent than previously thought, even for species with long larval durations (Cowen and Castro, 1994; Limouzy-Paris et al., 1997; Jones et al., 1999; Cowen et al., 2000; Swearer et al., 1999; Warner and Cowen, 2002; Swearer et al., 2002; Sponaugle et al., 2002).

A major unanswered question in marine ecology is the degree of connectedness between local populations. Put another way, what proportion of young arriving to a local population are products of local production? What is the source of recruits for any local population, and where do young produced in a local population go (Warner and Cowen, 2002)? Both dispersal and retention are likely larval transport pathways in many marine systems (Swearer et al., 2002). What remains unknown are the temporal variability and the intensity of these connections among populations and their importance relative to self-recruitment in the structuring of local marine populations.

Settlement patterns of demersal fish are the consequence of biological and physical processes operating on the larval stages during the transition from a pelagic to a benthic existence. The number of larvae that reach a location and settle determines the intensity of local recruitment. Larval supply can be influenced by current patterns, whereas settlement can be influenced by substrate selection behavior. Subsequent post settlement movements and mortality can also affect the distribution of demersal fishes and mask initial settlement patterns.

The temporal pattern of planktonic larval settlement, occasionally resembles a pulse form, and has been correlated to the vertical transport and water displacements during the pass of internal waves. If the water column is thermally stratified, the vertical displacement of water can be registered with fixed temperature sensors. Fast changes of 2 °C to 5 °C in only minutes can be indicative of internal waves and could indicate horizontal water advection (Pineda, 1991). Using drogues, Shanks (1983) demonstrated effective shoreward transport of up to 1 to 2 km in only in 2 or 3 hours. The occurrence of seiches along Puerto Rico's insular margins and tidally forced internal waves in the Caribbean basin (Capella, pers. comm.) could be a critical factor for larval recruitment or for triggering spawning events with the intrusion of subsurface colder waters.

In a study off La Parguera, using *Thalassoma bifasciatum* as a model species Appeldoorn et al. (1994) and Hensley et al. (1994) tested the hypothesis that coral reef fishes select spawning places and times that result in eggs being quickly dispersed outside the reef area. The results obtained did not support the hypothesis, but rather showed only a small net transport of eggs outside of the coast. These results indicated the existence of physically governed mechanisms of eggs retention within the coastal area, where eclosion of *Thalassoma* eggs occurred.

A pronounced coastal-oceanic gradient was found for most Hawaiian fish larvae by Leis and Miller (1976). Those species with neritic pelagic habits were evenly distributed in relation to distance from the coast. The reef fish larvae from pelagic eggs were more abundant offshore. According to Leis and Miller (1976) this offshore distribution is the result of passive movement with currents. In contrast, the maintenance of coastal and neritic distribution patterns requires an active behavior of animals, probably helped by currents, including tidal reversals and possible coastal upwelling (Leis, 1982). Ramírez (2000) obtained horizontal and vertical ichthyoplankton distributions off La Parguera that agree with the theory that most of reef fishes with pelagic eggs have mainly offshore larval distributions, while demersal spawners and estuarine species are found nearby the coast.

The multispecific ichthyoplankton aggregations found near the shelf edge off La Parguera by Ramírez (2000) were similar to results from others studies carried out in Guayanilla Bay east of La Parguera by García et al. (1995) and González (2002). In Ramírez (2000), total fish larval abundance declined across the neritic-oceanic gradient and coral reef fish larvae were numerically dominant assemblage as far as 29 km offshore, but declined markedly to very low abundance at 46 km where oceanic type larvae prevailed. However, horizontal distribution pattern of coral reef fish larvae was taxon specific. Meanwhile, Rojas (2002) also found declining abundances across the neritic-oceanic gradient, and reef fish predominated until 29 km offshore off the west coast of Puerto Rico, concluding that the Mona Channel could be acting as a barrier to larval dispersal from the Puerto Rico shelf.

Different types of oceanographic features have been invoked to explain potential consequences for larval dispersal. Although oceanographers cannot yet specify the pattern of water movement in close proximity to complex topography such as reefs, there is a range of small to mesoscale oceanographic features that provide opportunities for predictable transport of larval fish: eddies, upwelling systems, surface slicks, currents flowing along the coast (Mora and Sale, 2002).

Cowen and Castro (1994) noted strong agreement among the distribution of coral reef fish within the convergences of flows around Barbados, moving away from the coast and returning flows. They considered topographical variations, certain coastal currents at half water depth, and the active behavior of the larvae as the most important factors governing the observed larval distribution patterns. Sponaugle and Cowen (1996) further argued that two scales of processes defined the possible return and distribution of eggs and larvae around Barbados. At the smaller scale are the tidal currents, which are regular and predictable, that contribute to the return of the advanced larval development stages. Superimposed over this on the larger scale are less predictable events that also influence transport toward the coast. Similarly, Lee and Williams (1999) indicated that the Atlantic coastal waters of the Florida Keys consist of two distinct flow regimes: the nearshore region where current variability is primarily controlled by tidal and wind forcing, and the outer shelf, seaward of the reef tract, where current variations are caused by a mix of wind and Florida Current forcing from transient occurring gyres, eddies and meanders.

Another known mechanism that influences the spatial-temporal larval distribution and subsequent recruitment processes is the effect caused by internal waves (Pineda, 1991) and their associated surface slicks (Shanks, 1983). Internal waves can play a crucial role in the transport of larvae toward the coast. Abrupt decreases in nearshore water temperature, which can last for days, result from the advection of sub-superficial cold water from internal tidal waves, which may transport associated deep-water larvae into the coastal zone. Internal waves perpendicular to coast and their subsurface upwelling can be predicted following lunar cycles.

Until recently it was thought that pre-flexion larvae (before they complete development of the unpaired fins, principally the caudal fin) were unable to actively oppose existent currents. Now it is recognized that there are behavior patterns that can actively determine the vertical position of eggs and fish larvae in the water column, allowing transport by favorable currents toward suitable settlement sites and that larvae can actively orient to specific physical and biological cues, once swimming capabilities are developed, with this capability increasing with total development of locomotory structures (Kingsford et al., 2002; Mullineaux and France, 1995; Cato, 1992).

The purposes of this study were: 1) to target the full pelagic phase of a single species, the red hind, along an inshore-offshore gradient in La Parguera, taking advantage of its limiting spawning in space and time; 2) to characterize the temporal oceanographic and hydrodynamic conditions that prevailed and governed the retention/dispersive behavior of eggs and larvae during the red hind spawning season; and 3) to characterize the temporal taxonomic ichthyoplankton composition and its relation to the prevailing oceanographic conditions.

MATERIALS AND METHODS

Study Area:

La Parguera is located in the north Caribbean basin on the southwest coast of Puerto Rico, communicating to the west with the Mona Channel and to the east with Guanica and Guayanilla Bays. La Parguera is considered one of the most productive sites for marine commercial fisheries in Puerto Rico where the shelf extends for approximately 11 km, having a depth of 18 m to 22 m at the shelfedge. After the shelfedge there is a drop to 410 m, and then a continuous increase to 3860 m at 17° 30’ N latitude. The south coast of Puerto Rico is characterized by a mean westerly flow (Wüst, 1964; Gordon, 1967; Molinary et al., 1978; Appeldoorn et al., 1994).

Field Procedures:

Ichthyoplankton sampling was designed to cover the period when red hind, *Epinephelus guttatus,* historically aggregate in known spawning grounds. Ten ichthyoplankton sampling cruises were conducted off La Parguera, Puerto Rico during 1997, at intervals of 7 to 12 days before, during and after the reproduction events that annually take place at “El Hoyo”, near the shelfedge. Sampling dates were January 24, January 31, February 7, February 19, February 27, March 6, March 14, March 21, April 3 and April 9. Dates were chosen to correspond to lunar phases, as spawning in the red hind is generally associated with the full moons in January and February. On each date a meridional north-south transect, perpendicular to La Parguera coast, was occupied by six sampling stations. The first three nearshore stations were over the insular platform (neritic) and the following three were beyond the shelf edge (oceanic). The stations were selected approximately at 3, 4, 5, 6, 9 and 12 nautical miles from coast (5.5, 7.4, 9.2, 11.1, 16.6 and 22.2 km respectively), hereafter named stations 3, 4, 5, 6, 9 and 12. The particular spawning aggregation site of interest was “El Hoyo” located at 17°52.5’ N and 67°2.9’ W on the inner side of the shelfedge (Figure 3). The mean sampling stations coordinates are given in Table 3.

Table 3: Mean positions of ichthyoplankton sampling stations off La Parguera coast.

Distance from the coast (nautical miles / km)	**Shelf Position**	**Sample Start**	**Sample End**
3 nm / 5.5 km	shelf	17°57.205’ N -- 067°02.262’ W	17°56.693’ N -- 067°01.985’ W
4 nm / 7.4 km	shelf	17°55.823’ N -- 067°02.376’ W	17°55.467’ N -- 067°02.522’ W
5 nm / 9.2 km	shelf	17°53.833’ N -- 067°02.585’ W	17°53.656’ N -- 067°02.789’ W
6 nm / 11.1 km	Shelfedge	17°52.234’ N -- 067°03.041’ W	17°52.153’ N -- 067°03.129’ W
9 nm / 16.6 km	Oceanic	17°49.250’ N -- 067°02.992’ W	17°48.972’ N -- 067°03.070‘ W
12 nm / 22.2 km	Oceanic	17°46.220’ N -- 067°02.989’ W	17°45.935’ N -- 067°02.986‘ W

Sampling was originally designed to cover three discrete depths ranges at all stations to evaluate the temporal vertical distribution of eggs and fish larvae. However, due to navigation hazards in hard weather conditions, breakdown of trawling nets and eventual loss of the tucker trawl during another concurrent study in Mayagüez Bay discrete vertical sampling had to be dropped. Subsequently, sampling consisted of oblique tows covering the entire depth range (see below). Three replicates were made at each station.

For the first three cruises (Jan-24, Jan-31 and Feb-7) a 1-m^2 tucker trawl system with three opening-closing nets of 202 ɥm mesh and integrated flow meters was used. At all stations except station 6, three replicates were sampled in continuous oblique tows. Stations 3, 4 and 5 were sampled from 0 to 15m depth range, while stations 9 and 12 were sampled from 0 to 60m. At station 6 triplicates of three discrete depth ranges (0-20m, 21-40 m, and 41-60 m) were sampled in vertically stratified oblique tows.

After the accidental loss of the tucker trawl, samplings were conducted using a Bongo net, equipped with two 202 цm mesh nets and standard flow meters to measure the field-filtered volumes sampled. The two samples collected in each Bongo tow were combined as one sample, and the total volume filtered was calculated by adding the readings of both flowmeters. The volume of seawater per sample filtered during this project ranged between 72 to 487 m^3 with an overall mean of 240 m^3. The tow duration ranged between 3 to 9 minutes, depending on station depth, plankton abundance and winch efficiency in different sea conditions. Generally, onshore stations were sampled for 3 minutes and offshore stations for 4 minutes, with an overall mean of 4.2 minutes.

Samples were preserved in a mix of 70% alcohol and 30% of sea water, to avoid the dissolution of the calcified structures of larvae and developing embryos inside eggs. Egg and larval abundances were related to specific moon phases and associated to their probable natural spawning times.

To homogenize all cruises as continuous oblique tows, samples from the first three cruises over the discrete depths (0-20), (21-40) and (41-60) at 6 nm, were combined as three continuous (0-60) m samples. To combine the tow abundances for each replicate R1 (0-20, 21-40, 41-60), R2 (0-20, 21-40, 41-60), and R3 (0-20, 21-40, 41-60), the abundances at each depth stratum were first calculated and a water column mean value was obtained for each replicate from the same tow. These three water column (0-60) mean densities were then averaged for a total mean abundance for each identified fish family at 6 nm. This procedure allowed for better weighting when different filtered volumes occurred between samples.

Additional plankton samplings were carried out at “El Hoyo” and at “La Pasa del Medio”, near Turrumote Cay (7.4 km from the coast) (Figure 3) on 12 March 1998. In that year, red hind spawning was, for some reason, retarded compared to previous years. The selected day was the third full moon of the year, and red hind were still ripe showing gregarious reproduction behavior. The samplings were performed at three depths (surface, mid column water and near to bottom), using a 0.5-m diameter conical net with 202-µm mesh. The volume filtered (approximately 50 m^3) was enough to characterize the vertical distribution of eggs during this unusual red hind spawning event. Because these samples were obtained by scuba-diving and that diving time was limited, replicates were not collected.

From January to April 1997 three current meters were deployed on La Parguera shelf to determine the potential flow of eggs and larvae. Flow patterns together with distribution data from plankton tows may allow hypotheses to be formulated regarding the possible developmental and/or behavioral strategies utilized by larvae to ensure adequate levels of recruitment by the red hind and the other major taxa collected.

Current meters were deployed at depths of 8, 13 and 9 m (near mid-column water depths) at three stations over the La Parguera shelf (Figure 3). An InterOcean S4 current meter was deployed at 17° 55.877’N, 67° 02.270’W (Pasa del Medio). The S4 measures water speed, direction and temperature. Two AANDERAA RCM9 current meters were deployed at 17° 53.630'N, 67° 03.206'W (El Hondo) and at 17° 52.648'N, 67° 03.132'W (close to the shelfedge "Veril") (Figure 3). The RCM9 measures currents and also optionally records water temperature, conductivity, and optical transparency. All three current meters sampled at five-minute intervals. The S4 collected data from January 29 to March 6 while both RCM9s sampled from March 7 through April 8.

Conductivity, temperature, chlorophyll-a, σ-t, density and pressure related to depth were measured using a SBE 19 CTD profiler (Sea-Bird Electronics, Inc.) with an integrated Wet Labs, Inc. fluorometer. CTD casts were made at each sampling station starting February 19 when the instrument became available for our project. Some casts at farthest stations could not be performed due to weather conditions. An additional CTD profile was made in October 1997, with castings at stations 3, 6 and 9 to examine water properties and stratification during a period outside the red hind spawning season.

Naval Layered Ocean Models (NLOM) were obtained from the Naval Research Laboratory to show the large scale flow south of Puerto Rico. These models utilize TOPEX/POSEIDON and ERS satellite data on sea surface height anomalies. The analyses were restricted to the upper layer of the model (65 m), where all ichthyoplankton samplings were performed. The East Caribbean subregion modeled covers the area bounded by the following longitudes and latitudes: (70˚0'W to 60˚0'W, 10˚0'N to 20˚0'N) and includes the ichthyoplankton sampling area (68˚0'W to 65˚0'W and 16˚0'N to 18˚0'N).

The model output includes **H1** = upper layer thickness of the model, **SSHB** = baroclinic sea surface height and **VEL1** = upper layer velocity, for the four month time range, beginning January 1, 1997 to April 30, 1997. Outputs were presented in video format with mean daily frames for each region. These modeling outputs were used to hypothesize possible farfield egg and larval dispersal, current trajectories and connectivity through current ring translations in the East Caribbean subregion. The NLOM model can be perceived as the farfield extension that follows the smaller scale nearfield results, obtained with the current meters deployed over the shelf in La Parguera during the 1997 red hind spawning aggregation event.

Laboratory phase:

All collected ichthyoplankton samples were entirely sorted and analyzed for fish eggs and larvae and maintained in a mix of 70% alcohol and 30% of sea water. Taxonomic identifications under a binocular dissecting microscope were made to family level on all identifiable larvae. The references consulted during the identification phase were: Borrero et al. (1978), Kendall (1979), Lindeman (1986), Riley et al. (1995), Jones et al. (1978), Leis and Rennis (1983), Moser et al. (1984), Collins et al. (1980), Matarase et al. (1989), Leis and Trnski (1989), Richards (1989), Baldwin (1990), Powel and Tucker (1992), Ditty and Shaw (1994), Richards (1994), Richards et al. (1994), Comyns (1994), Farooqi et al. (1995), Moser (1996) and the most complete compilation to date for larval fishes from the Central Atlantic, Richards (2000).

Larval fishes were classified as preflexion or postflexion, based on the urostyle flexion, which precedes the formation of the caudal fin. All family abundances are reported as Ind/100m^3 to match and facilitate the comparison with previous ichthyoplankton works done for Puerto Rico (García et al., 1995; Ramírez, 2000; Rojas, 2002, and González, 2002). All eggs were measured to their nearest 0.01mm and larvae to their nearest 0.05mm.

Egg and larval spatial and temporal distribution patterns were analyzed and correlated to oceanographic and hydrodynamic conditions.

RESULTS AND DISCUSSION

1. Oceanographic Results:

1.1- Temporal Temperature Profiles:

Temperature profiles over time are presented to illustrate the changing conditions that occurred during the red hind spawning season and period of field sampling. Particular attention is given to the 25.5 to 26° C temperature stratum, as this represents the conditions under which red hind spawning is assumed to have taken place.

The October temperature profile (Figure 18) is shown first to illustrate water temperature properties outside the natural red hind spawning season. The temperature shows a clear stratification of the water column and a homogeneous surface mixed layer with temperatures between 29˚ C and 29.5˚ C extending down to the thermocline located at 60 m depth. The 25.5˚ C to 26 ˚C temperature stratum was located at 71-75 m depth at station 6 and 80-84 m at the station 9.

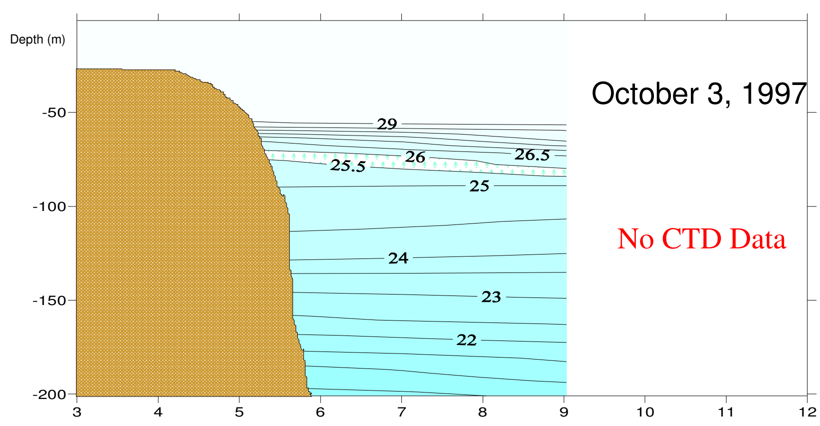


Figure 18. Vertical temperature (°C) profiles during October 3, 1997. CTD castings were taken at stations 3, 6 and 9 only.

The earliest (January 29-March 7) temperature series recorded during the study was from the S4 current meter deployed at mid depth at “La Pasa del Medio” (Figure 19), that spatially corresponds to the ichthyoplankton sampling station 4. A gradual decrease in temperature, which lasted until February 2, was observed from the moment the S4 was deployed. After February 2, temperature rose over 26° C until February 15 when again it decreased below 26° C. Sustained temperatures in the 25.5-25.75° C range were observed from February 16 until the end of the recording period. The temperature time series indicates that the period of expected peak spawning overlapped the seasonal period of minimum temperatures (February 15-March 7). Daily oscillations in the temperature record reflect the effect of diurnal heating/cooling and possible minor tidal effects.

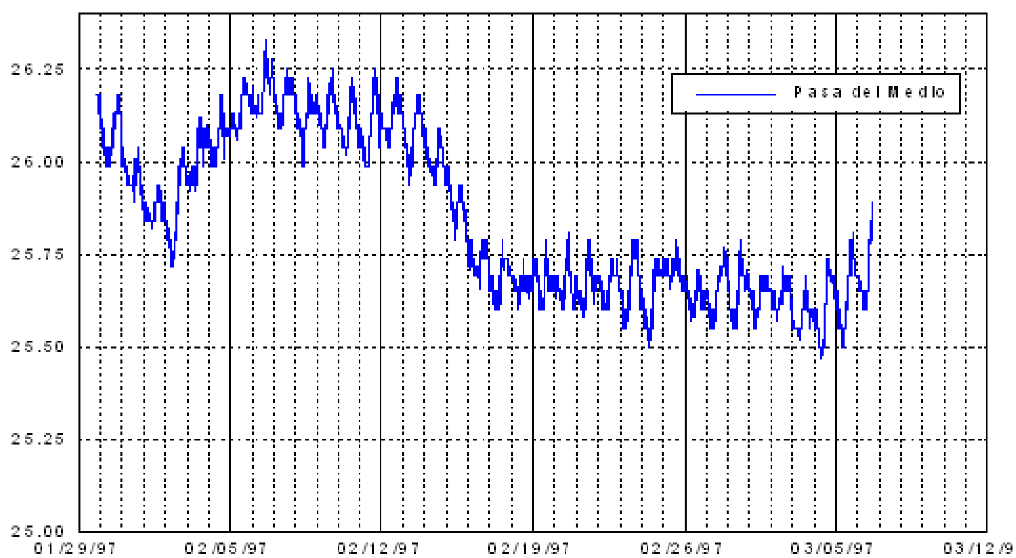


Figure 19. Parguera shelf temperature time series collected from the S4 current meter in “La “Pasa del Medio” during January 29 to March 7, 1997.

The first CTD temperature profile during the period of ichthyoplankton sampling was for February 19, 1997 (Figure 20A). This shows that the coastal and near-shelf regions had lower temperatures (25.5°C–26°C) than the offshore surface mixed layer which was over 26°C. Thus, the temperature over the shelf measured by the S4 current meter and the CTD cast were the same. These cooler coastal waters were continuous with an offshore subsurface temperature layer found at 75 m depth. This surface water cooling was probably governed by a combination of different factors, such as wind driven surface mixing (as the main force leading to downward cooling), some extent of onshore Ekman transport drift of the subsurface layer (induced by westerly surface currents), mixing by tidal currents, and to a lesser extent, seiching of water across the Caribbean basin (see the inclination of the thermoclines (higher nearshelf)). The temperature series recorded by the S4 current meter (Figure 19) indicates that coastal water cooling began on February 15.

The next CTD temperature profile, taken at February 27, 1997 (Figure 20B), shows a wide homogeneous low temperature (25.5-26˚C) mixed layer, which extends offshore down to 79 m depth at station 6, and to 94 m at station 12. Figure 20C, from March 6, 1997 shows a very similar profile, except that the 25.5˚ C isotherm

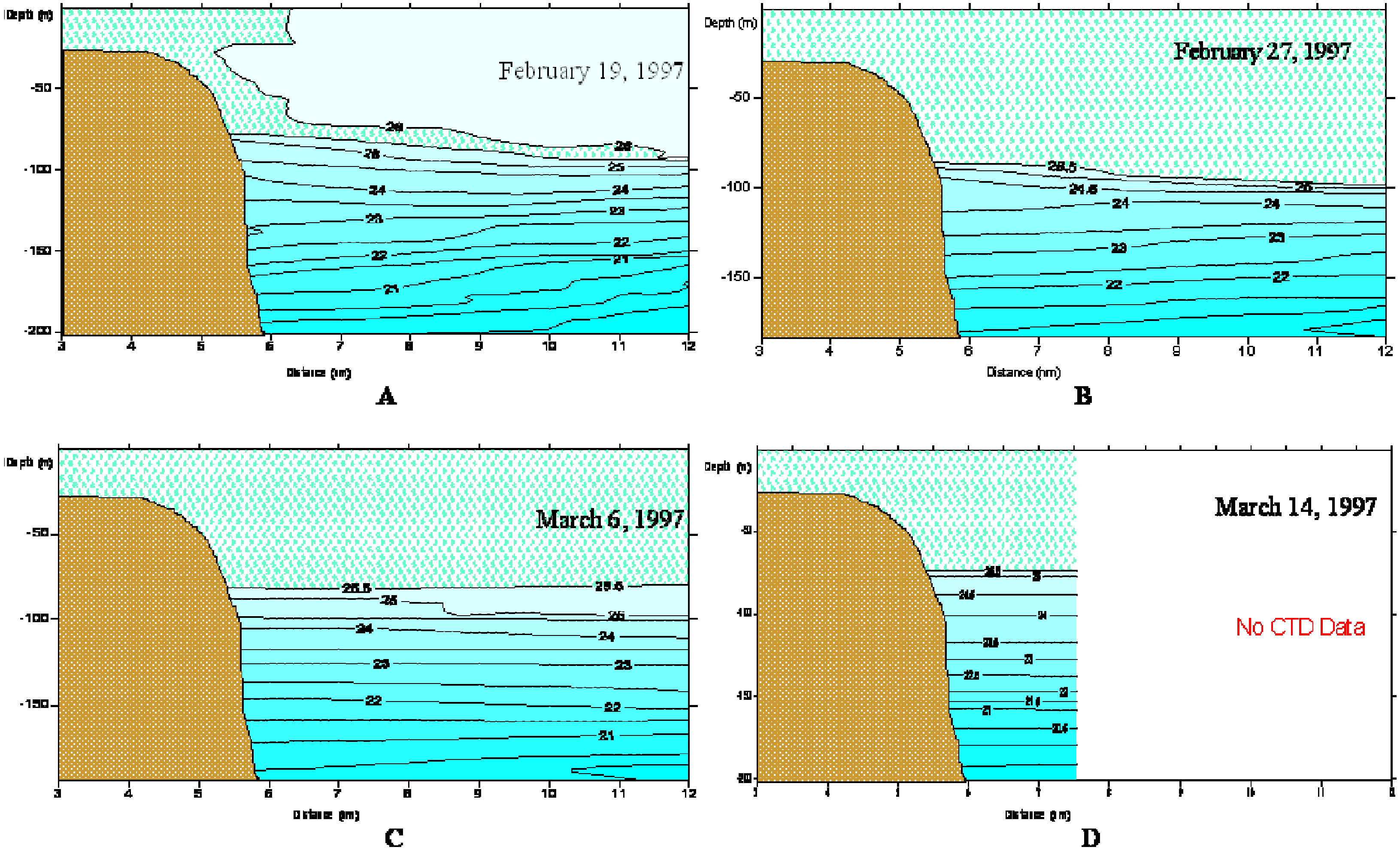


Figure 20: Vertical CTD Temperature profiles, on an inshore-offshore transect off La Parguera, Puerto Rico. Sampling dates are in figures. For A, B, C, F, G and H castings were done at all stations, D castings were at stations 3, 4, 5 and 6, and E castings at stations 3,4, 5, 6 and 9, only. The specially marked water mass (25°C-26°C) represents conditions under which red hind spawning occurred.

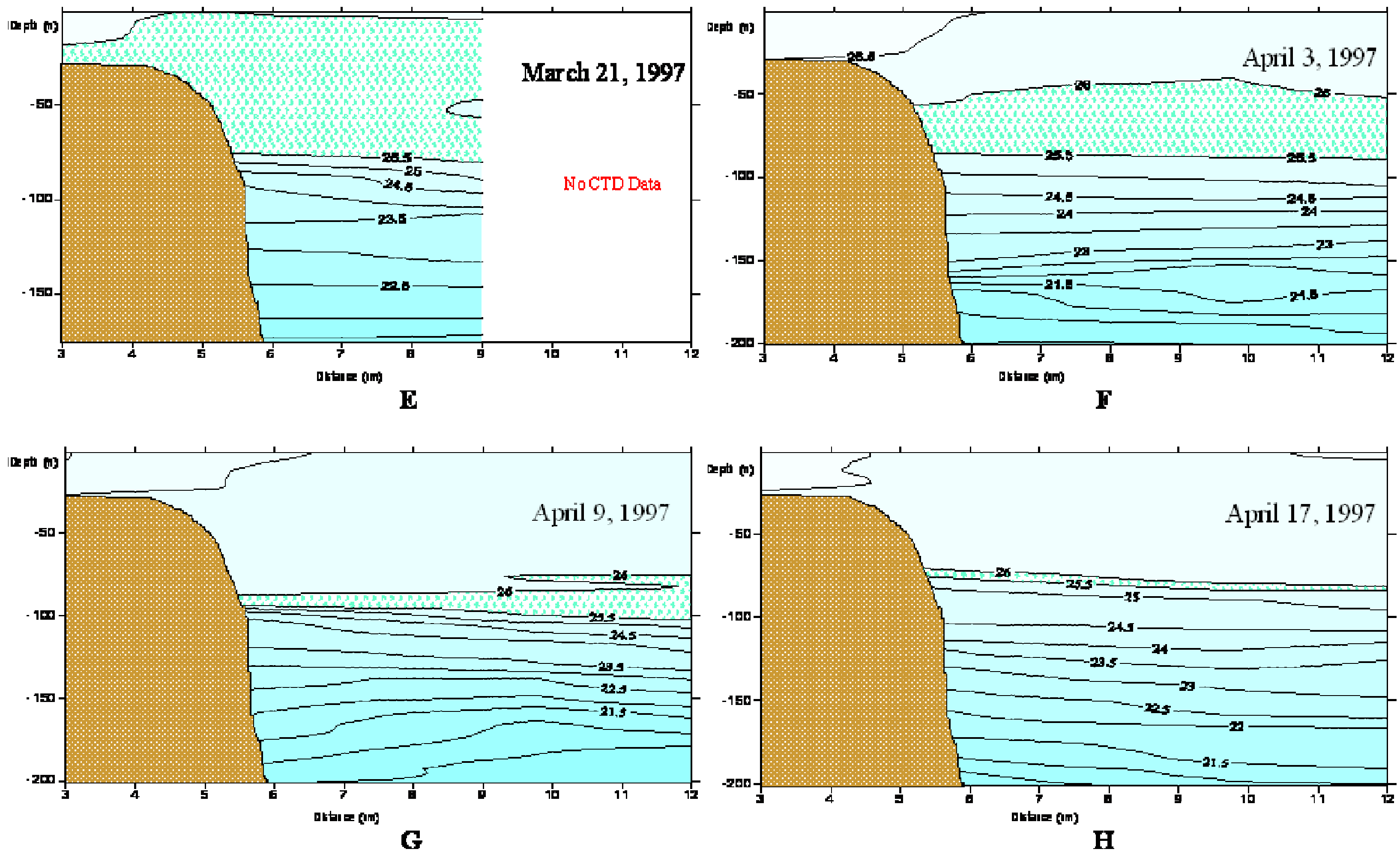


Figure 20 (Cont.): Vertical CTD Temperature profiles, on an inshore-offshore transect off La Parguera, Puerto Rico. Sampling dates are in figures. For **A, B, C, F, G** and **H** castings were done at all stations, **D** castings were at stations 3, 4, 5 and 6, and **E** castings at stations 3,4, 5, 6 and 9, only. The specially marked water mass (25°C-26°C) represents conditions under which red **hind spawning occurred.**

was nearly flat and found at shallower depths (81 m at the station 6 and at 80 m at the stations 9 and 12, thus narrowing the surface mixed layer.

On March 14 (Figure 20D) the depth of the surface cold mixed layer continued to decrease. At this time the 25.5˚ C isotherm was found at 75 m depth at station 6, the last station where CTD data were collected during this cruise. Weather conditions prevented additional CTD casts at the outer stations.

The subsequent temperature profiles (Figures 20E to 20H) show a gradual restoration of warmer surface water and the resulting confinement of the 25.5 °C to 26 °C stratum to subsurface layers, when red hind reproduction ended.

On March 21 (Figure 20E) warmer water appears in the surface waters over the shelf. The deep water over the shelf still ranged from 25.5˚ C to 26˚ C, and offshore the 25.5˚ C isotherm was found at 77 m depth at station 6, and 80 m at the station 9. By April 3 (Figure 20F) the temperature over the shelf and offshore had increased to over 26˚ C, and the 25.5–26˚ C layer was between 38 m to 86 m depth. The last two temperature profiles from April 9 and April 17 (Figure 20G and 20H) showed a total confinement of the 25.5–26˚C layer to depth. On April 9 this layer was found between 86-94 m at station 6, 75-102 m at station 9 and 85-99 m at station 12. By April 17 the 25.5–26˚ C stratum had thinned and was found at depths ranging 72 m to 83 m.

Figure 21 presents the temperature series collected with the RCM9 current meters at mid water depth in El Hondo (station 5) and at the shelf edge (Veril, close to the red hind spawning ground) from March 7 to April 8 (1997). These RCM9 series corroborate the temperatures profiles obtained from CTD casts during the same period (Figures 20 a-c). They also show that temperatures at El Hondo and at the shelf edge remained similar until March 20, when differing temperature fluctuations started, suggesting that different processes were affecting these areas at this time.

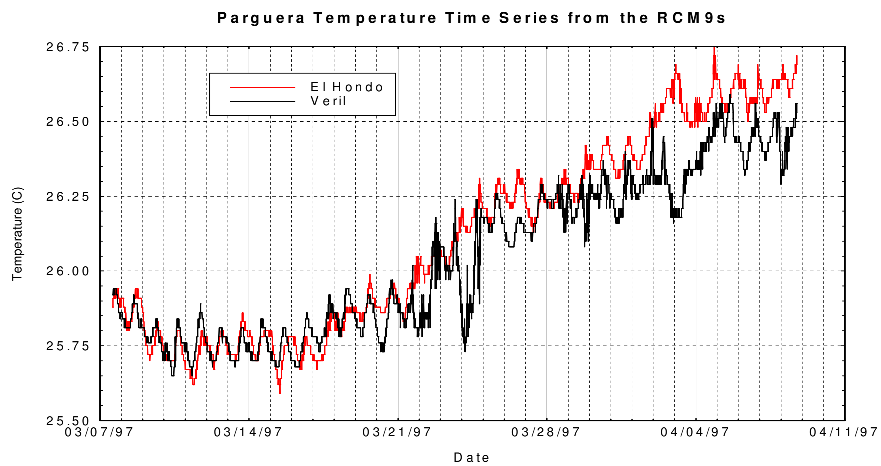


Figure 21. Parguera shelf temperature series collected from the RCM9s current meters in “El Hondo” and the shelfedge “Veril”, during Mach 7 to April 8, 1997.

1.2- Temporal Chlorophyll-a Profiles:

The temporal sequence of chlorophyll-a profiles (Figures 22 and 23) are presented to characterize phytoplankton standing stocks during the red hind spawning event (RHSE) sampling period. These profiles show maximum values inshore over the shelf and at around 100 m depth, but with some temporal variations. Chlorophyll-a concentrations ranged from near zero at greater depths to 3.19 µg/l over the shelf; mean values at 100 m depth were 1.6 µg/l, ranging from 1.28 µg/l to 2.13 µg/l.

The chlorophyll-a profile for October 3, 1997 (outside the red hind spawning season) (Figure 22) shows a high concentration over the entire shelf, while the offshore

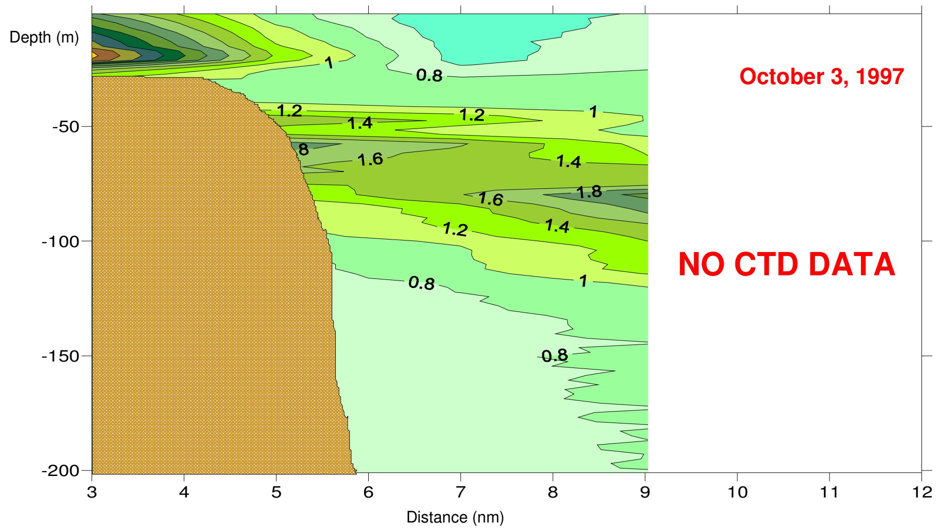


Figure 22. Vertical chlorophyll-a profile for a transect perpendicular to the La Parguera coast, Puerto Rico during October 3, 1997. Chlorophyll-a in (μg/l). CTD profiles were made at Stations 3, 6 and 9 only.

concentrations were scattered through different depth layers, with concentrations over 1 μg/l located between 43-99 m at station 6 and 55-120 m at station 9, with maximum values at 59 m for station 6 and 80 m for station 9. This profile differs from the general offshore profiles obtained during the RHSE, where higher concentrations over 1 μg/l had thinned and had more defined depth ranges (Figure 23).

Comparing the chlorophyll-a profiles obtained for February 19 (Figure 23 A) and February 27 (Figure 23B), the main difference is that for February 27 a higher chlorophyll-a concentration was found over the shelf, extending over the red hind spawning grounds at the shelf edge and through the neritic-oceanic interphase (station 6). Curiously, this pattern was found only on this sampling date. The seemingly higher chlorophyll-a concentration at this time may represent a favorable temporal habitat for

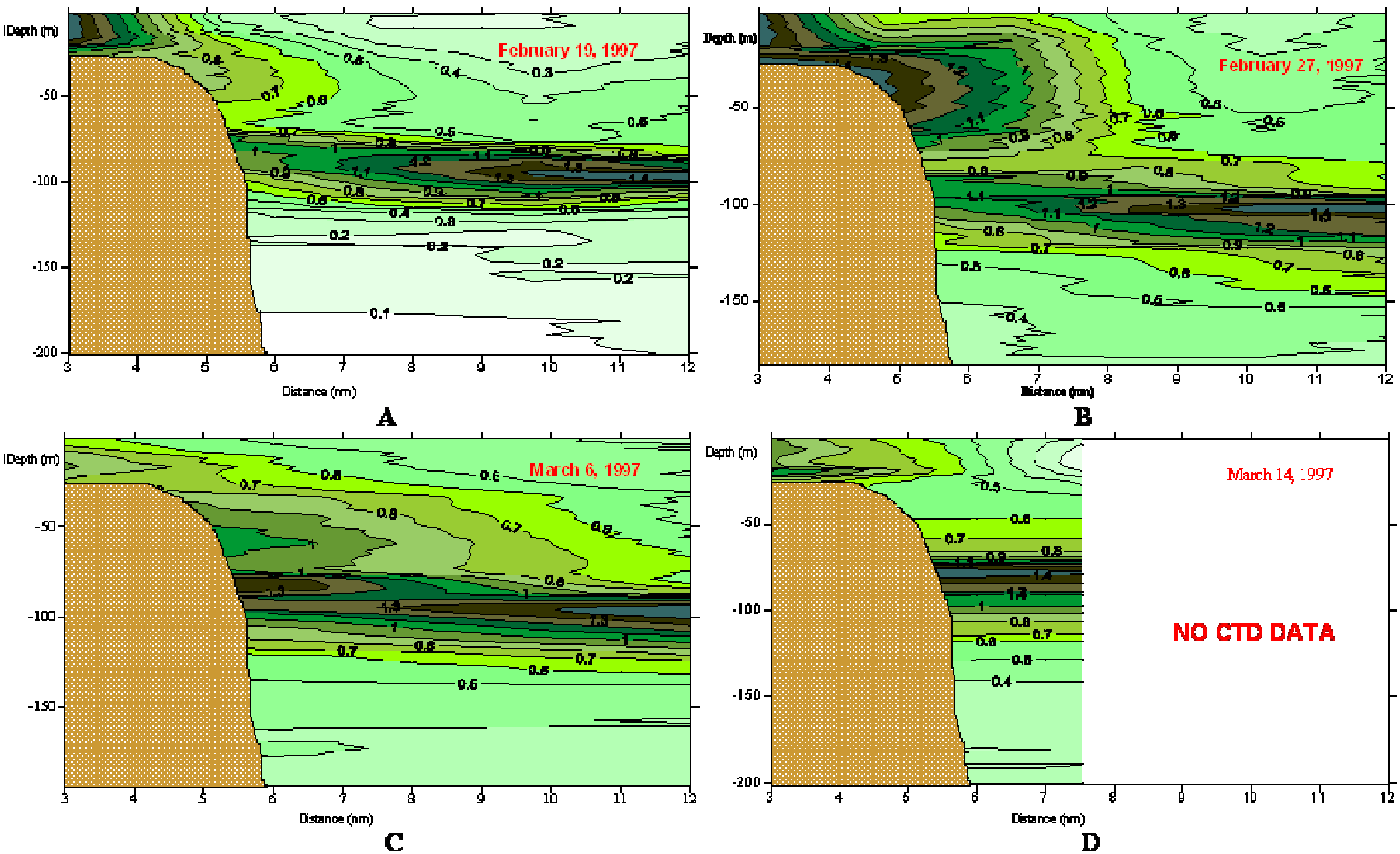


Figure 23. Vertical CTD chlorophyll-a profiles (µg/l), on an inshore-offshore transect off La Parguera, Puerto Rico. Sampling dates are in figures. For **A**, **B**, **C**, **F**, **G** and **H** profiles were done at all stations, **D** profiles were at stations 3, 4, 5 and 6, and **E** profiles at stations 3,4, 5, 6 and 9, only.

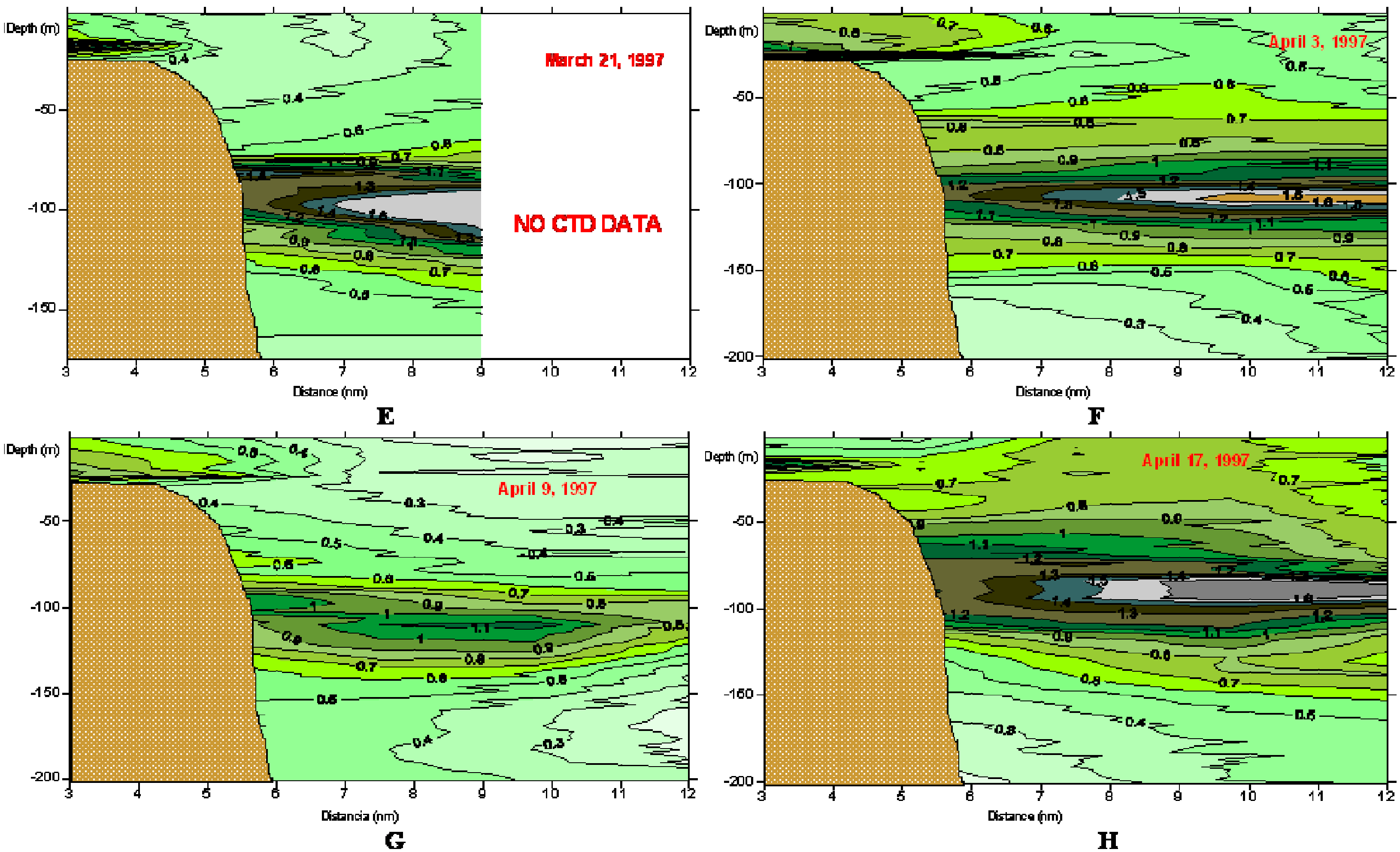


Figure 23 (cont.). Vertical CTD chlorophyll-a profiles (µg/l), on an inshore-offshore transect off La Parguera, Puerto Rico. Sampling dates are in figures. For A, B, C, F, G and H profiles were done at all stations, D profiles were at stations 3, 4, 5 and 6, and E profiles at stations 3,4, 5, 6 and 9, only.

early larval fish development in terms of food availability. A narrow depth range with high concentrations prevailed offshore in almost all the RHSE chlorophyll-a profiles, with some variations in mean depth, but always near the 100 m (Figures 23A-H).

The vertical chlorophyll-a profile at station 6 during Feb-27, 1997 (Figure 24) showed two depth ranges with distinctive high concentrations. The first maximum was located at 40 m depth having greater concentration of chlorophyll-a and a wider depth range than the second found below 85 m. Ramírez (2000) reported similar high concentrations of chlorophyll-a at the same station in Feb/95, but with lower overall concentrations, and the profile had a more continuous shape. Again, these high chlorophyll-a concentrations could represent important sources of food for reef fish larvae, with the maximum at 40 m representing the first feeding realm where the onset of exogenous feeding occurs. The second chlorophyll-a maximum position, below 85 m, would more likely serve as a feeding source of larvae in more advanced development stages, with swimming capabilities and complete control of buoyancy.

1.3 Salinity and Sigma-T temporal variations:

During the RHSE, the salinity and density structure of the water column off the shelf-edge at La Parguera (Station 6) was characterized by permanent stratification with temporal variations on the surface mixed layer mean values, and fluctuations (65-92 m) of the halocline and picnocline depths (Figure 25). The February 19 cast showed the lowest values of both mean salinity and mean sigma-t in the surface mixed layer. Gradual

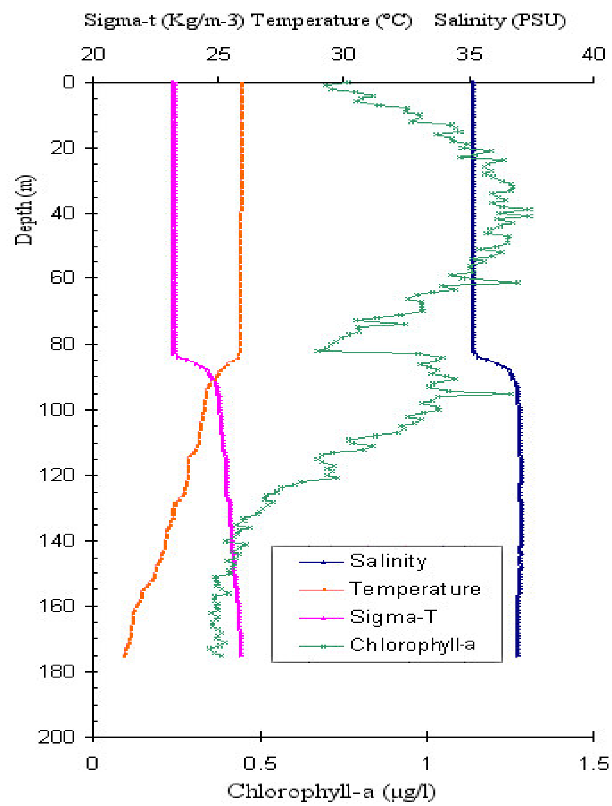


Figure 24. Vertical profile of chlorophyll-a (µg/l), salinity (PSU), sigma-t (kg/m^3) and temperature (°C) at station 6, during February 27, 1997.

increments were observed in salinity and sigma-t during all the consecutive samplings until April 3 when sigma-t decreased while salinity continued to increase until the next cruise (April 9), then decreased thereafter. The deepest halocline and picnocline (92 m) occurred on April 9, which corresponds to the deepest maximum cholophyll-a concentration found during the study (Figure 20G). February 27 showed two chlorophylla-a maxima (Figure 22B and 23). The shallower one covered almost the entire mixed layer while the deeper one characterized the thermocline, picnocline and halocline depth ranges.

Knowing from artificial rearing that viable red hind eggs and recently hatched larvae are mainly buoyant, one would expect that in nature, the majority would be found in the upper portion of the surface mixed layer. Therefore, they will develop under the conditions of this layer, at least during their early ontogenetic development.

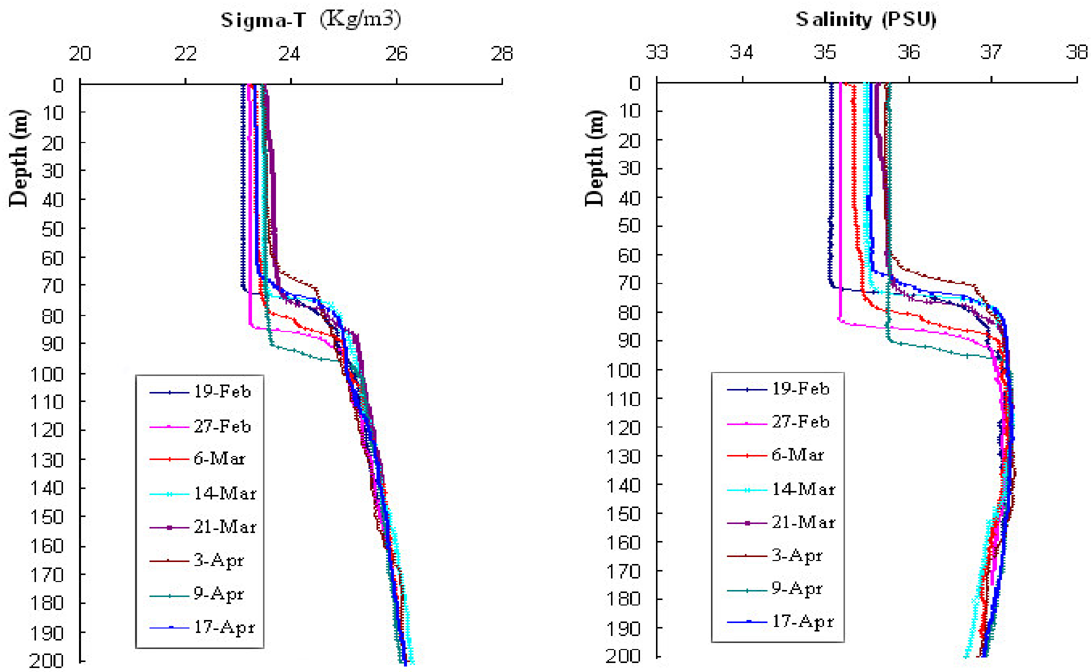


Figure 25. Vertical CTD profiles for sigma-t (Kg/m^3) and salinity (PSU) for station 6 nm, during eight ichthyoplankton sampling cruises covering a red hind reproduction event in 1997, off La Parguera, Puerto Rico.

Although red hind can spawn from January to March, it is well known that they reproduce in discrete aggregations at specific times, usually related to the first three full moons of the year. Temperature profiles suggest that if red hind aggregation began forming around the first full moon of 1997, it probably started concurrently with the rupture of the warm surface water and the drop in water temperatures caused by prevailing strong east-southeast winds and subsequent wind driven sea surface mixing.

If isolated red hinds spawned around this first full moon (January 24), (note: the mass reproduction aggregation is though to have occurred in February, around the second full moon, see below) resulting pelagic larvae should have approached or already achieved the settlement phase by March 6. This assumes red hind larvae behave similar or close to Nassau grouper (*E. striatus*), which have a planktonic larval duration of 30 to 45 days (Colin 1992). Larvae from the red hind spawning aggregation that occurred around the second full moon (February 22) would still have been developing, and settlement would not have yet occurred by March 6. On March 14, similar temperature conditions still prevailed, but by March 21 (near the third full moon of 1997, on March 24) these temperature conditions had changed and warmer water began to extend over the shelf, which would be expected to limit additional red hind reproduction. However, these warmer temperatures should not have been a major limiting factor for the early development stages. At this time all larvae, if any, spawned on the first full moon had finished settlement and those from the second full moon should have either settled or been near to settlement.

By April 3 the surface water temperatures were no longer similar to those that characterized the time of early ontogenetic development of the red hind. At that time the temperature over the shelf, and extending offshore, was over 26°C and increasing.

Including this study, all recent ichthyoplankton studies off Puerto Rico (García et al., 1995, Ramírez, 2000, González, 2002, and Rojas, 2002) had sampled only the first 60 meters of the water column. However, the presence of deeper thermoclines, picnoclines, haloclines and related higher chlorophyll-a concentrations could be playing a major role during the late development stages of fish larvae, if natural food availability and concentrations are favored at these depths. Future ichthyoplankton studies at these deeper strata's may yield interesting results with respect to fish ontogenetic development, dispersal vs. self recruitment and useful information for fisheries management purposes.

It is well known that strong winds blowing along a coastline can generate upwelling or downwelling through Ekman transport (Sponaugle et al., 2002). The 1997 winter-spring sampling period was characterized by very strong winds from the east-southeast. The typical winter regime of calm weather during cold fronts and strong winds in-between was obscured by this very persistent wind flow.

Alongshore flows in typical upwelling/downwelling systems are on the order of 10's of cm s^{-1} (Sponaugle et al., 2002). Onshore Ekman transport in the upper layer along a downwelling coast can enhance larval retention and recruitment into local waters (Lee and Williams, 1999). Larvae spawned into an upwelling event could be transported 10's of kilometers alongshore. However, upon a reversal in the winds and the onset of downwelling, these larvae could be transported back toward the site from which they were spawned, (Sponaugle et al., 2002). This upwelling front may limit the extent of the offshore dispersal of larvae. If the upwelling shows an alongshore spatial discontinuity it could be acting as a barrier to larval dispersal too, promoting the self recruitment of populations.

Both commercial fishermen and fisheries managers have observed that red hind spawning at the aggregations off La Parguera (southwest) and the spawning grounds on the Mona Passage along the west coast of Puerto Rico, (Tourmaline, Abrir la Sierra, and Bajo el Sico reefs) were not concurrent. These differences in timing could be related to different mixed layer wind-driven cooling processes or alongshore Ekman drift. The wind driven surface mixing and potential subsurface layer Ekman onshore transport would be limited to the southwest coast due to the relationship of wind and current flow relative to the east-west orientation of the southern coastline. Markedly different wind and flow characteristics would have to exist along the Mona Channel for similar processes to occur.

1.4- Current and Oceanographic modeling results:

1.4.1- S4 and RCM9 Current Meter Results:

The east-west and north-south current components and water speed followed at mid water column depth through January 19, 1997 at “La Pasa del Medio” and through March 7 to April 8 at “El Hondo” and the shelf break “Veril”, are used to explain the main physical forces governing any particle forming part of the pelagic realm over the La Parguera shelf, during the period of ichthyoplankton sampling. The descriptive statistics of current flow registered with the S4, and the two RCM9 current meters are presented in the Table 4.

Tidal currents are the main source of variability in the flow time series. Tides along the south coast of Puerto Rico are principally diurnal (one cycle per day) and the U (east-west) current time series clearly show the principally diurnal variability in the flow. The diurnal and semidiurnal tidal components are modulated by the lunar declination so

Table 4. Flow statistics for one S4 (January 29 - March 6, 1997), and two RCM9 (March 7 – April 8, 1997) current meters deployed in La Parguera shelf. (-) equal westward.

	S4 ("La Pasa del Medio")	**RCM9 ("El Hondo")**	**RCM9 ("Veril")**
No. of points	51946	9331	9331
mean u (cm s^{-1})	-6.57306814	-2.62691736	-2.40955544
mean v (cm s^{-1})	-2.24888968	-0.08220127	-1.35994768
mean scalar speed	7.65282393	4.96622944	6.85219240
mean vector speed	6.94713831	2.62820315	2.76684213
mean direction (˚)	251	268	241
mean temp (˚C)	25.8484917	26.1169205	26.0446129
u variance	21.0336895	26.3320904	39.6955452
u std dev	4.58624983	5.13148022	6.30044031
v variance	8.79983521	3.84642100	17.5532227
v std dev	2.96645164	1.96122944	4.18965673
s variance	19.5310116	12.4201641	17.9475574
s std dev	4.41939020	3.52422523	4.23645592
temp. variance	0.047573924	0.106567979	0.06.979119
temp. std dev	0.218114480	0.326447517	0.2641

that a weak semidiurnal tide is prevalent for several days each month. The sampling period covered an instance of large-amplitude tides, which occurred when the lunar perigee coincided with the plenilunium, in February of 1997. The currents over La Parguera shelf in spring of 1997 can therefore be modeled as a linear superposition of a mean south-southwest flow and a diurnal oscillatory tidal component (Capella, 1999).

All three current meters showed a south south-west main current direction, but the higher mean current speed, -6.573 cm/ s^{-1} to the west (U), occurred during the first period (January 29 to Mach 6), when lower temperatures prevailed in the area and when red hind were spawning. However, currents at this station should also have been topographically constrained to a greater westward flow, relative to currents measured further out on the shelf.

In order to better illustrate flow characteristics, three series of progressive vector trajectories were simulated. The starting time for each simulation was defined as one week prior to each ichthyoplankton sampling cruises, ending the day of the cruise.

All four weekly progressive vectors from the S4 current meter at La Pasa del Medio, covering the January 31 to March 6 period (Figure 26), showed strong displacement of water to the south south-west. All progressive vectors had one week displacements of over 40 km from their starting points. Figure 27 presents the east-west current component for the S4 current meter deployed at “La Pasa del Medio”. Only short, non-sustained current reversals (to the east) were observed during the period, and are associated with diurnal and semidiurnal tidal flow variability. This suggests that pelagic eggs and larvae sampled during the corresponding cruises resulted from spawning fishes located upstream of the study area; the magnitude and consistency of the flow is indicative of how far these larvae could have been transported. Similarly any eggs and recently hatched larvae spawned from La Parguera would have had low probabilities of local retention until they develop swimming capabilities. Late-stage larvae under the same hydrodynamic conditions can orient toward different reef stimuli (Tolimieri et al., 2000, Leis et al., 2002) and are capable of independent movement. They can swim at field speeds of between 5 and 50 cm s^{-1} (20 cm s^{-1} average) (Leis and Stobutzki, 1999) and for long enough to cover between 4 to 200 km before exhaustion depending on the species (Stobutzki and Belwood, 1997, 2002; Leis and Stobutzki, 1999).

The second full moon of 1997, when mass aggregation red hind spawning should have occurred, was under the above oceanographic conditions. Expectations, thus, are that the probability of finding different ontogenetic phases of red hind larvae would be low, and might only be possible if additional natural spawning aggregations were located upstream.

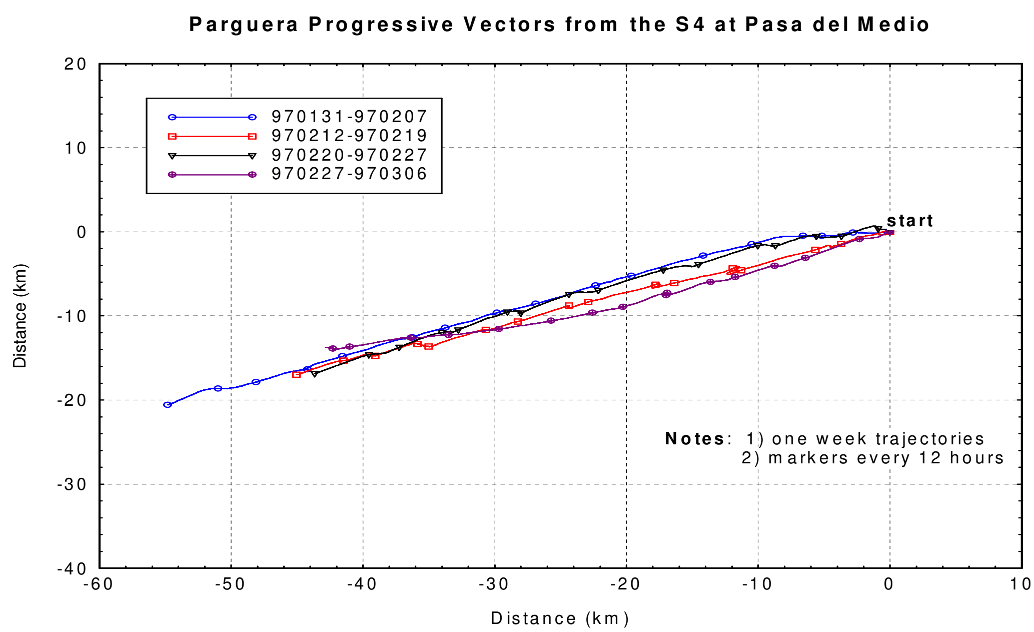


Figure 26. Progressive vector simulations from the S4 current meter at La Pasa del Medio from January 31 to March 6.

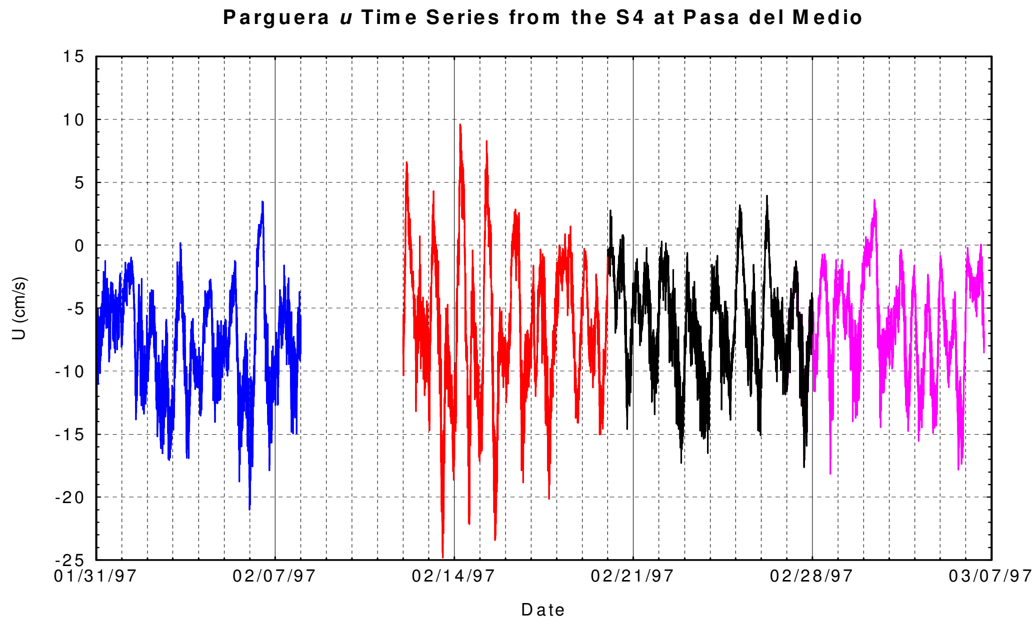


Figure 27. Parguera u time series from the S4 current meter at "La Pasa del Medio" during January 31, 1997 to March 6, 1997. Color codes represent intervals used on progressive vector simulations.

The Progressive vector trajectories simulated for the outer shelf region at "El Hondo" and the shelf edge "Veril", through March 7 to April 8, 1997, are shown on Figures 28 and 29. Each graph shows five consecutive one week simulations.
At both stations, the first two weeks (97/03/07-97/03/14 and 97/03/14-97/03/21) of simulations had a consistent flow to the west near to, or over 30 km/week. The main difference observed between stations during these first two weeks is that at El Hondo the transport to the south was less than 4 km, while the shelfedge station presented a transport of 6 km for the first week and 20 km during the second week. According to these results, all passive particles will be dispersed offshore if the force acting over the area is the same as recorded from the instrument deployed over the shelf.

At both stations, the first two days of the third week (97/03/27-97/04/03), had almost the same behavior as the preceding weeks, but during the last five days a clear water mass retention event occurred in the area (better visualized at the shelfedge station, Figure 29, black line). The retention event began on March 22, 1997 and continued through the following week (97/03/27-97/04/03), with almost a static condition for both stations (in purple). This retention period lasted for12 days, followed by an additional week (97/04/02-97/04/08) of a low level of net easterly flow (in green). The corresponding u components of these two stations are presented in Figures 30 and 31. In both graphs it was clear that the calm (retention) period was only affected by tidal current variability. All vector velocities are summarized for better visualization in

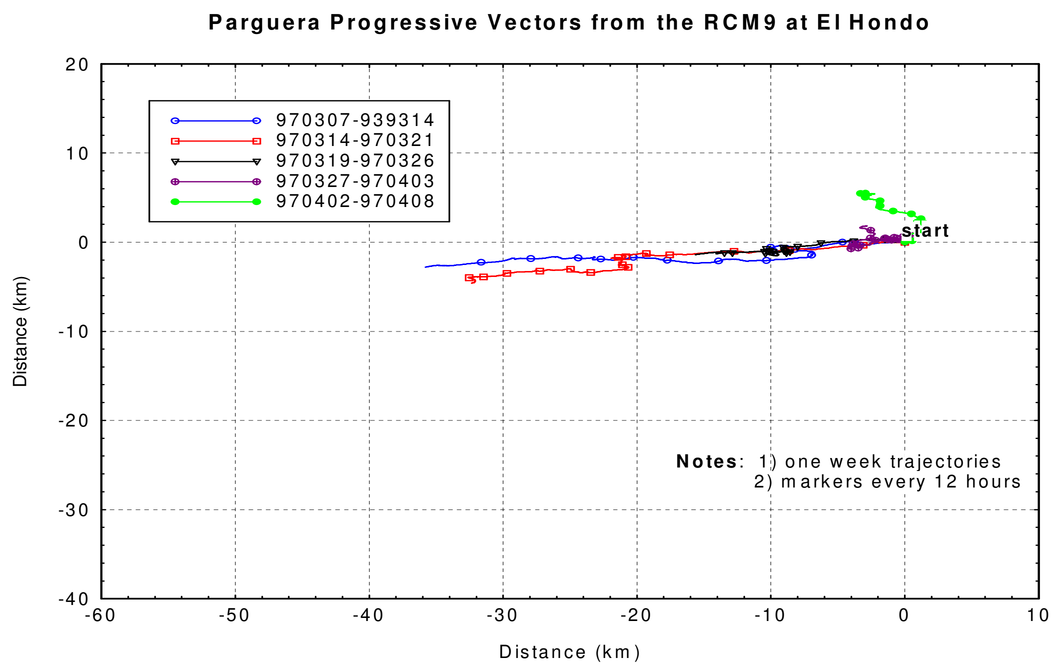


Figure 28. Progressive vector simulations from the RCM9 current meter at "El Hondo" off La Parguera, Puerto Rico, from March 7 to April 8.

the rose of trajectories (Figure 32). Based on these data, expectations are that during this period, sampled larvae would be representative of the eggs and newly hatched larvae potentially spawned from La Parguera area.

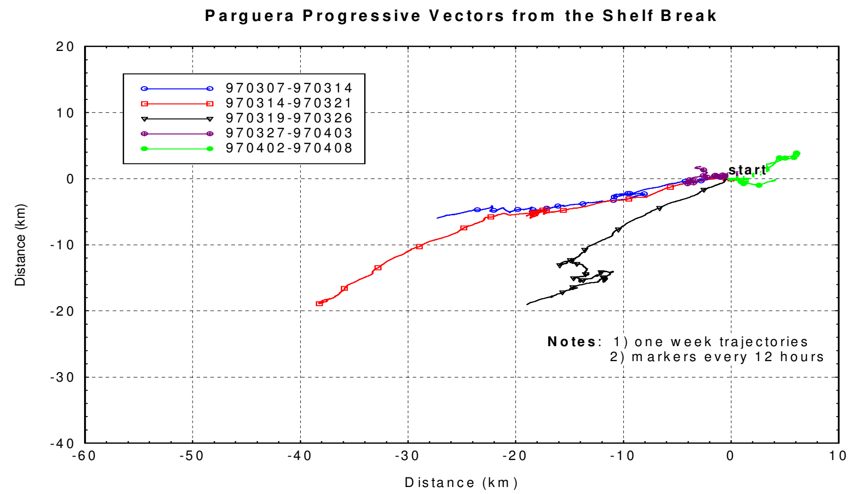


Figure 29. Progressive vector simulations from the RCM9 current meter at the shelf break "Veril" off La Parguera, Puerto Rico, from March 7 to April 8.

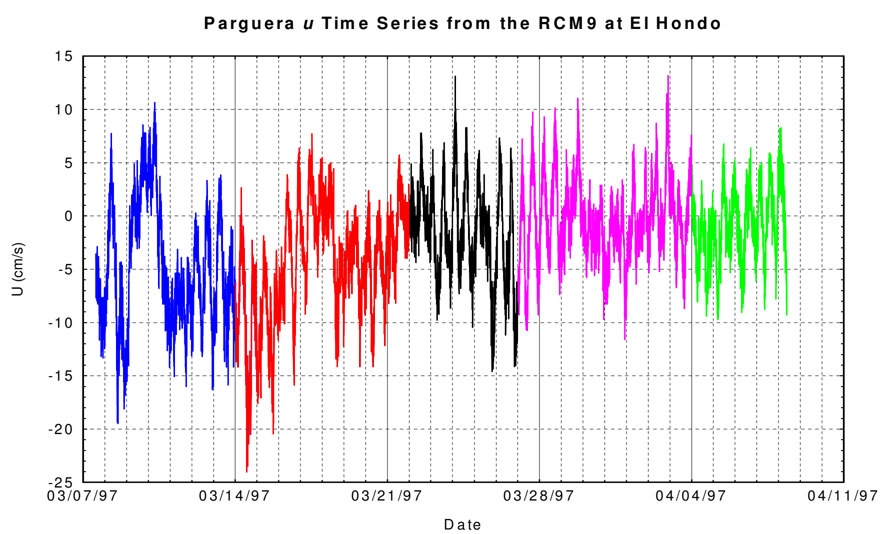


Figure 30. Parguera u time series from the RCM9 current meter at "El Hondo" during March 7, 1997 to April 8, 1997. Color codes represent intervals used on progressive vector simulations.

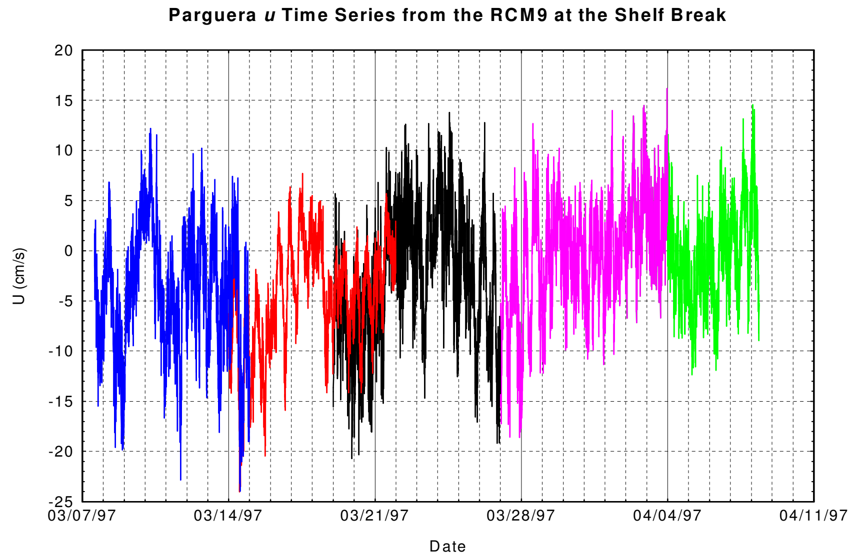


Figure 31: Parguera u time series from the RCM9 current meter at the shelf break "Veril" during March 7, 1997 to April 8, 1997. Color codes represent intervals used on progressive vector simulations.

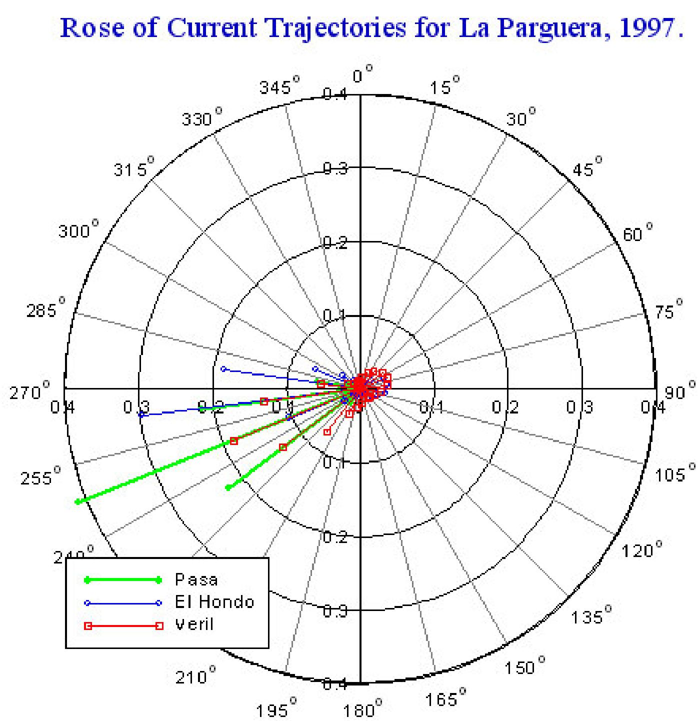


Figure 32. Rose of trajectories for "La Pasa del Medio" (S4) and for "El Hondo" and the shelf break "Veril".

1.4.2- NLOM current simulations.

From the different types of output formats provided by the Naval Research Laboratory - Ocean Dynamics and Prediction Branch (NRL-ODPB), the current velocity vector output was used to illustrate patterns of flow in the far field. This output shows in a 2-dimmensional array the upper layer (65 m) velocity vectors, which represent an average over the thickness of the upper layer.

The NLOM current simulations cover the period from January 1, 1997 to April 30, 1997. These data were originally provided in video format, but for presentation purposes, selections of specific clips corresponding to ichthyoplankton sampling dates are used.

The dispersal pattern of eggs and larvae off La Parguera should be interpreted as being influenced by two distinct hydrodynamic conditions: 1) the shelf hydrodynamic conditions, which are mainly influenced and governed by seasonal winds, onshore Ekman drift, tidal currents variability, seasonal air temperatures, and possible occurrences of internal waves (Capella, pers. comm.), and 2) the offshore hydrodynamic conditions, which are extremely variable in current speed, current direction, and the occurrence of gyres that spend several days transiting the area, sometimes close to shelf but generally more offshore.

In general, the northern Caribbean mesoscale hydrodynamic forces may inhibit offshore (i.e. southward) dispersal of propagules from the south coast of Puerto Rico, thus enhancing the possibility of self replenishment, but not ruling out the possibility of long distance dispersal under certain conditions. Eggs and larvae without sufficient swimming capabilities to oppose the entrapping or advecting forces of gyres, unusually close to shore, or of sustained strong surface currents to the west, can be transported long distances, although mortality under these circumstances can increase if environmental conditions do not comply with developmental requirements, thus limiting the real success of dispersal. Larvae with swimming capabilities can receive continuous sensory information regarding the location of appropriate coastal habitats, and therefore may attempt to limit offshore dispersal (Swearer et al. 2002). Gyres in the Caribbean occur continuously and can travel hundreds of km before dissipation. It is commonly observed that rings formed in the Lesser Antilles frequently last for weeks, long enough to reach the Greater Antilles. Thus, some extent of long distance connectivity should not be discarded.

The NLOM graph series (Figures 33 to 43) shows strong west currents at the ichthyoplankton sampling stations during the initial sampling dates. The southern most station (In: 17˚46.220 N, 067˚02.989 W, Out: 17˚45.935 N, 067˚02.986 W) on January 24 (first full moon of the year) was bordering an eccentric extension of a large gyre advancing from the east (Figure 33). A clear retention area is found between the southwest corner of Puerto Rico and the Mona Channel. If spawning occurred around this first full moon, those larvae dispersed offshore could have been transported with and developed within this gyre, increasing the potential for retention. At this time, no further transport to the north was observed in the Mona Channel. Nearshore oceanographic conditions are not considered in the NLOM model. Thus, nearshore retention cannot be discarded but cannot be proved either. At the same time dispersed larvae could be seeding Mona Island if surface waters had favorable temperature ranges for the red hind ontogenetic development.

For January 31 (Figure 34) a broader west current could be observed in the southwest coast of Puerto Rico, while north currents were entering the Mona Channel, enhancing the possibility of west coast retention. Through February 7 (Figure 35) and February 19 (Figure 36) the surface currents showed a similar pattern but with a more defined north current entering the Mona Channel. This was followed by a relaxation of the north currents entering the Mona Channel on February 27 (Figure 37), but with the continuous west currents still along the southwest coast.

By the next sampling, March 6 (Figure 38), the north currents in the Mona Channel returned, and the continuous west current along the south coast was strong and broad. On March 14 (Figure 39) conditions along the southwest shelf remained similar, but the Mona Channel currents were again observed to change and now flowed to the south. The prevailing southwest currents through March 14 shown in the progressive vector diagrams obtained from the current meters deployed over the shelf correlate positively with the NLOM results, where west currents prevailed in the sampling area. The second full moon of the year (February 22), and related spawning and larval development occurred under these conditions, and larvae would have been transported to the west, with southern dispersal due to mixing or tidal currents.

On March 21 (Figure 40) two distinct gyres where present in the area, one in the south of the Mona Channel and the other near the shelf edge imparting an eastward flow in the offshore sampling area. By April 3 (Figure 41) the Mona gyre had ended, but prevailing southern currents were still present. Meanwhile, the southern gyre moved to the east, maintaining its position near the shelf edge. Retention probability at this time would be very high and eggs or larvae collected at this particular time would be expected to originate from the La Parguera spawning populations. Again, the visual correlations between NLOM (offshore model) and the progressive vectors (inshore model) are high and indicate conditions very different from the previous strong westerly flow during January 24 to March 14.

The current reversal to the east observed over the shelf during the last week of ichthyoplankton sampling (April 9) on the progressive vector diagrams also matched the results obtained from the NLOM model (Figure 42), where the latter showed weak westerly currents near the shelf edge. Currents near the west coast were moving north, while near Mona Island they were moving south. At this time all normal red hind larvae should have undergone settlement.

One week after the completion of the ichthyoplankton sampling (April 17), the NLOM model (Figure 43) showed an easterly current along the southwest coast of the island, evidently enhancing self replenishment of species that reproduced off La Parguera at this time, i.e., after the red hind reproduction season. Red hind recruits coming from the west coast spawning grounds of El Bajo de Sico, Tourmaline, and Abril la Sierra could be part of the plankton, but only if specific local conditions retarded spawning until the third full moon phase (March 24).

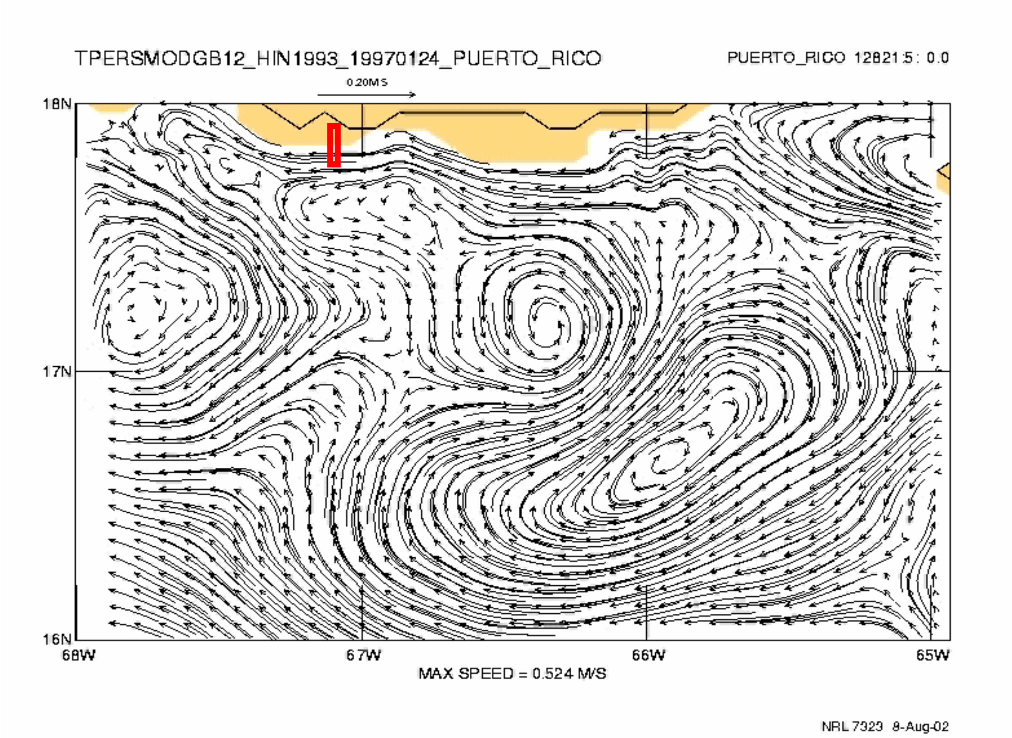


Figure 33. NLOM simulation for south Puerto Rico on January 24, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970124-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect).

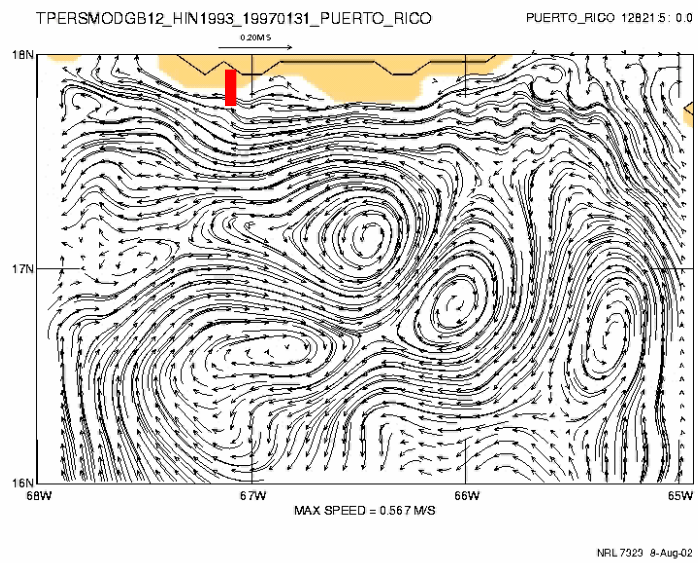


Figure 34. NLOM simulation for south Puerto Rico on January 31, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970131-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect).

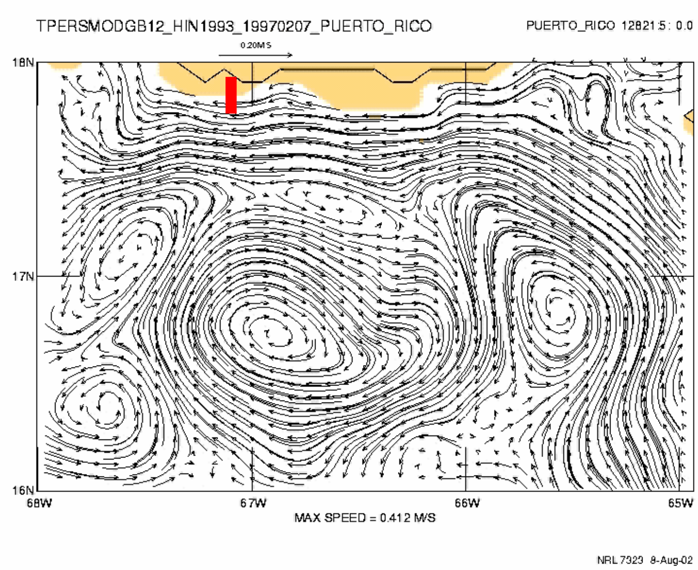


Figure 35. NLOM simulation for south Puerto Rico on February 7, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970207-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect).

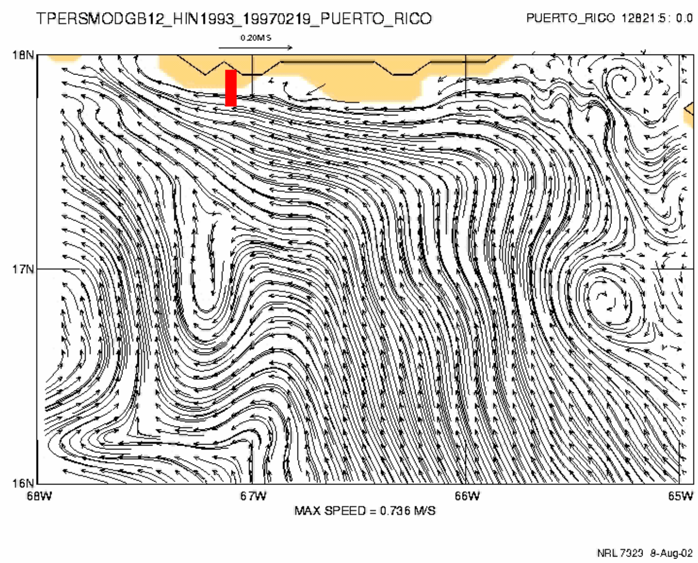


Figure 36. NLOM simulation for south Puerto Rico on February 19, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970219-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect).

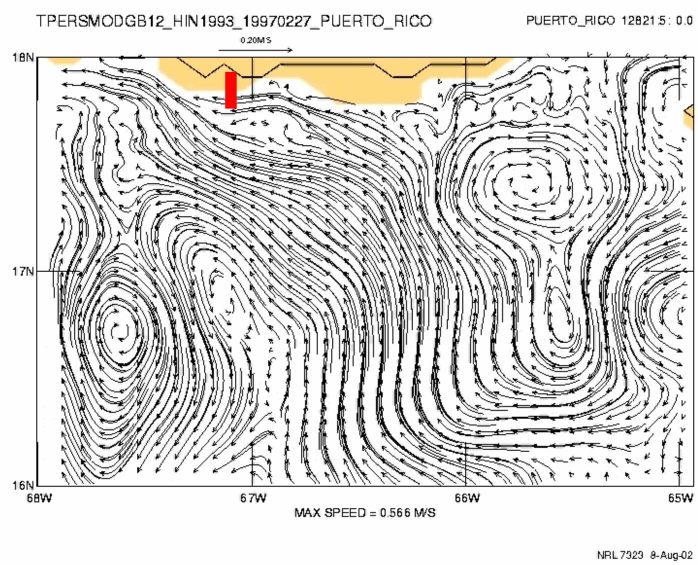


Figure 37. NLOM simulation for south Puerto Rico on February 27, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970227-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect).

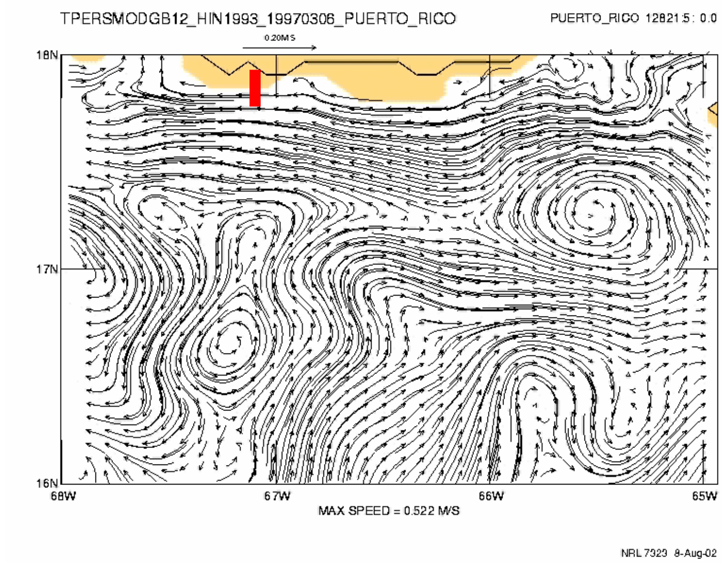


Figure 38. NLOM simulation for south Puerto Rico on March 6, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970306-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect).

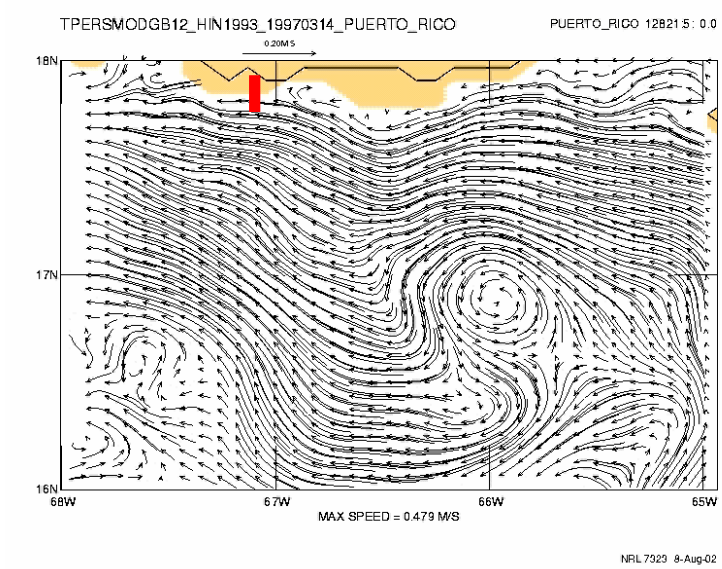


Figure 39. NLOM simulation for south Puerto Rico on March 14, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970314-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect).

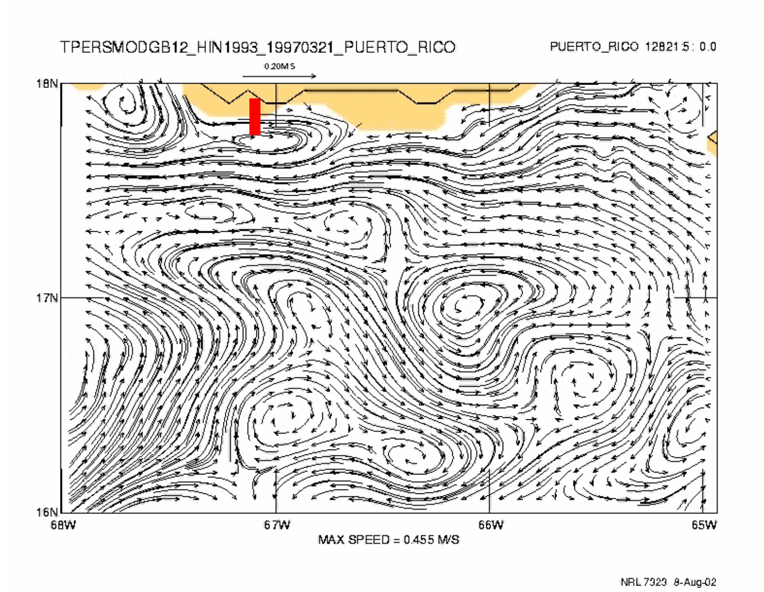


Figure 40. NLOM simulation for south Puerto Rico on March 21, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970321-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect).

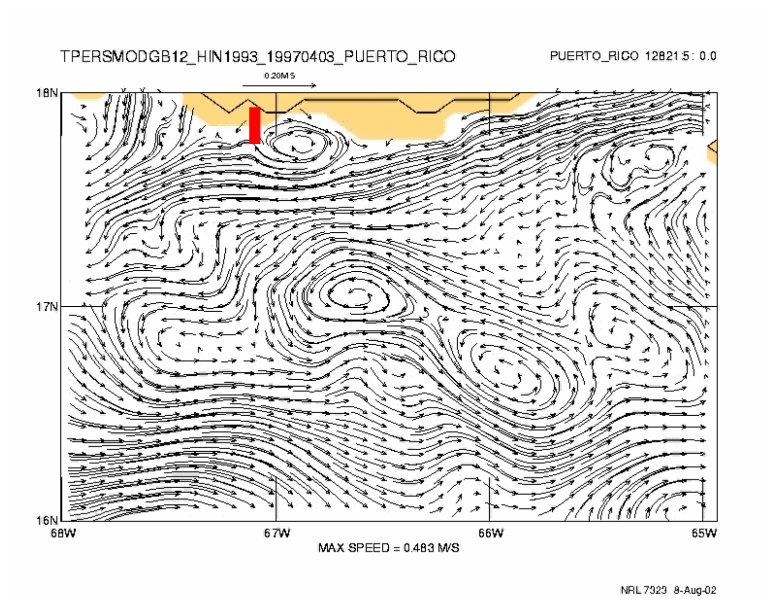


Figure 41. NLOM simulation for south Puerto Rico on April 3, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970403-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect).

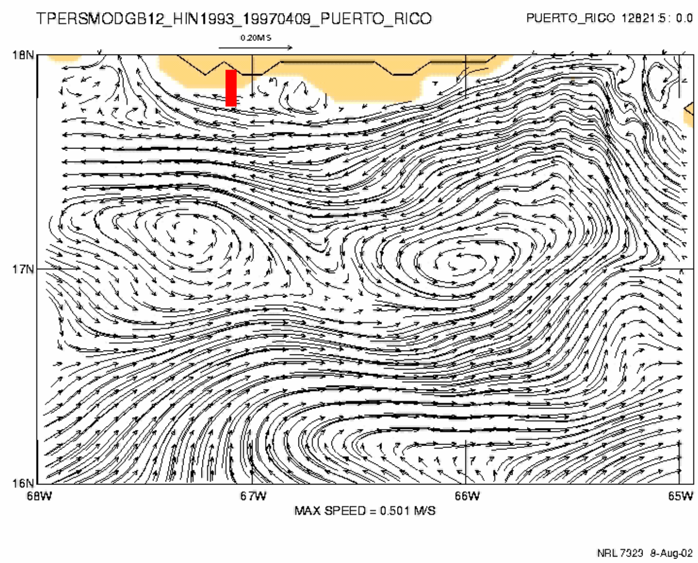


Figure 42. NLOM simulation for south Puerto Rico on April 9, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970409-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect)

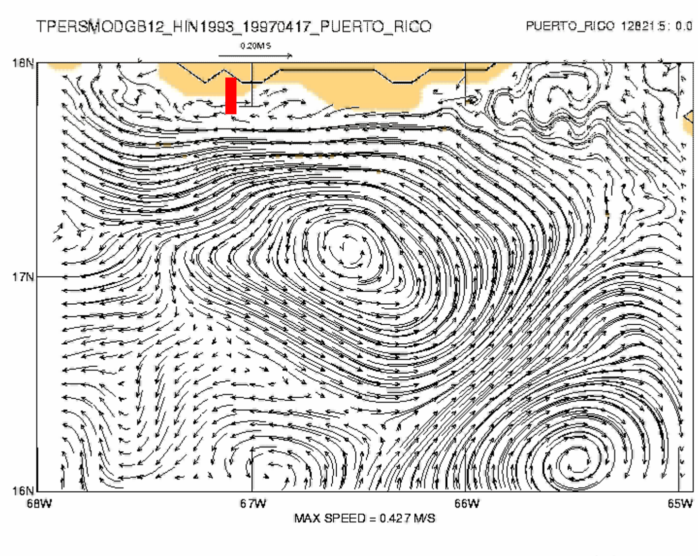


Figure 43. NLOM simulation for south Puerto Rico on April 17, 1997. TPERS-(Topex/Poseidon/ERS satellite data), MODGB12-(Mean used in satellite data assimilation), 1993-(hindcast beginning), 19970417-(Year-month-day), NRL-Naval Research Laboratory. Red rectangle (neritic-oceanic sampling transect)

2. Biological Results

2.1 Egg distribution and abundance.

Pelagic egg abundances and their temporal/spatial distribution are regulated by several biotic and abiotic factors: 1) spawning stock biomass, 2) spawning location, 3) egg behavior (sinking/floating/gradual density change with embryo development), 4) time until hatching, 5) predation on eggs, 6) species-specific fecundity, 7) mortality rate after fertilization, 8) surface mixing forces, 9) mean horizontal/vertical current directions and intensities, 10) tidal fluxes variability, 11) species-specific range of temperature for optimal ontogenetic development, and 12) water density stratification, among others.

A total of 86,591 eggs were collected and measured. The total mean abundances by sampling date are presented in Figure 44. Eggs were sorted by shape: oval, pointed or round. Of the total, 4,872 corresponded to oval (5.6%), 4,231 (4.9%) to pointed and 77,488 (89.5%) to round eggs. The round egg diameters ranged between 0.4 mm to 3.5 mm (Figure 45).

Many reef fish species share the same egg characteristics as *Epinephelus guttatus*: egg diameter range and a single oil globule. Then, it is not possible to differentiate between species by simple microscopic observation. More elaborate techniques like genetic differentiation need to be performed to identify eggs at the species level. Egg diameter range was used only as a general potential indicator of the red hind.

Knowing that viable red hind eggs float over their entire development t and that only due to surface mixing forces can the vertical distribution change, one can

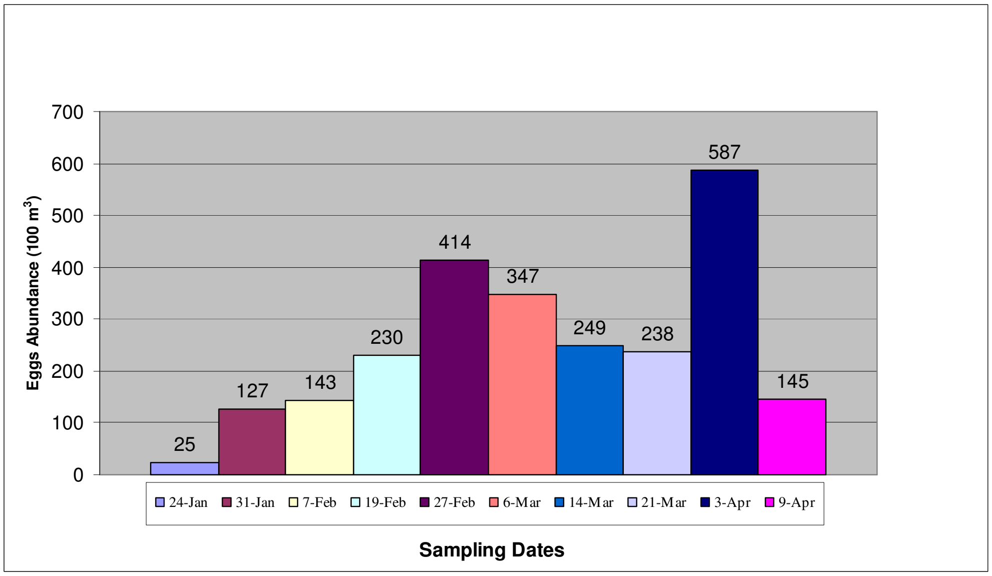


Figure 44. Total mean egg abundance sampled off La Parguera, Puerto Rico, by sampling date. Abundances are presented as eggs/100 m^3.

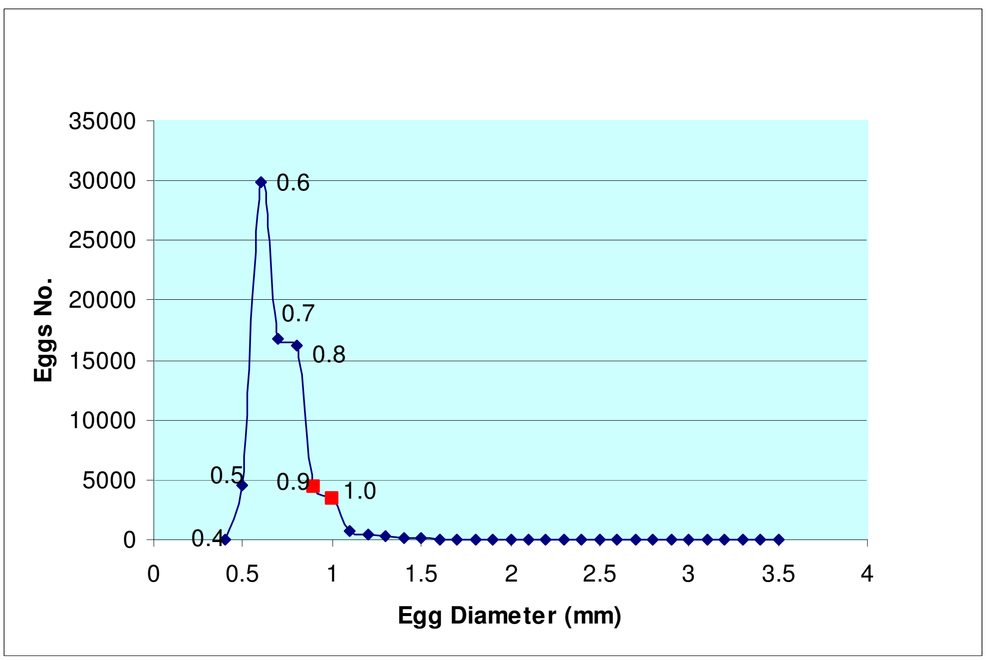


Figure 45. Round eggs diameter frequency distribution, from ten ichthyoplankton sampling cruises during 24-Jan to 9-Apr off La Parguera, PR. Red points indicate size range of red hind eggs.

assume they were passively advected from the spawning aggregation site near the shelf edge. Hatching should occur around 24 to 30 hours after fertilization under natural conditions, followed by at least by two days of purely passive drift. Dispersal to the west southwest should have occurred based on the progressive vector diagrams, with possible transport of 10 km per day. The prevailing strong west currents observed with the NLOM results, theoretically should deter massive offshore (i.e., southernly) dispersal. The majority of eggs collected during the sampling cruises from January 24 to March 23 were subjected to westerly dispersal forces. Meanwhile, from March 24 to April 3 when oceanographic retention processes were occurring, the ichthyoplankton collected included eggs that more likely represent local reproduction. And from April 3 to April 17 when mixed retention and easterly current reversions occurred, the collected propagules could be either from local or from western adjacent localities.

These patterns can be used to explain why low abundances of potential red hind eggs were present during sampling. Potential red hinds correspond to only 9.2 % of the total collected eggs and 10.4 % of the round eggs (Figure 45).

The large peak in abundance observed on April 3 (587 eggs/100m^3) (Figure 44) does not consist of potential red hind eggs. Rather, these eggs were generally smaller and were found inshore at the stations 3, 4 and 5 (Figure 46). Potential red hind eggs were limited to the inshore station 3 and probably represented other species.

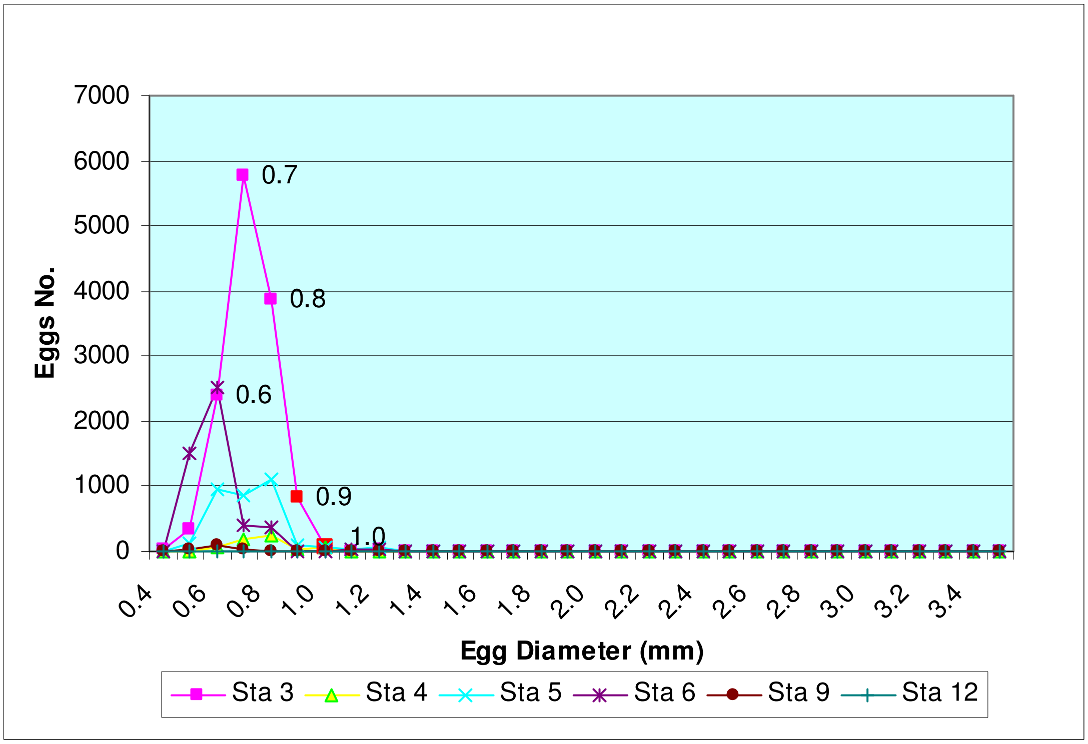


Figure 46. Eggs size frequency distributions by station on April 3, 1997, off La Parguera, Puerto Rico.

To better characterize the vertical distribution of eggs, additional tows were made by diving during the following (1998) red hind spawning season. Using commercial fishermen, the timing of the aggregation at El Hoyo was monitored. The aggregation began around mid February, but gonads were not ready for spawning at that time, illustrating the extent of annual variability that occurs. Plankton tows were made on March 12, the third full moon of the year. The results are summarized in Figure 47. Overall egg abundance decreased with depth, for both locations (El Hoyo and Turrumote Key), and for both egg types (developed and undeveloped). In particular, developed eggs were primarily found on the surface tows. Developing eggs were defined as those where the perivitelline space was visible, which should occur during the first thirty minutes after fertilization. El Hoyo showed much greater abundances than at Turrumote Key of total eggs, with the majority being undeveloped. The abundance of developing eggs was slightly higher in the surface waters of Turrumote Key compared to the same depth at El Hoyo, where red hind spawning took place. The proportion of undeveloped eggs, with abundance several orders of magnitude higher than those developing, suggests that sampling (beginning 08:30) occurred close to spawning time or that low egg viability was occurring in nature.

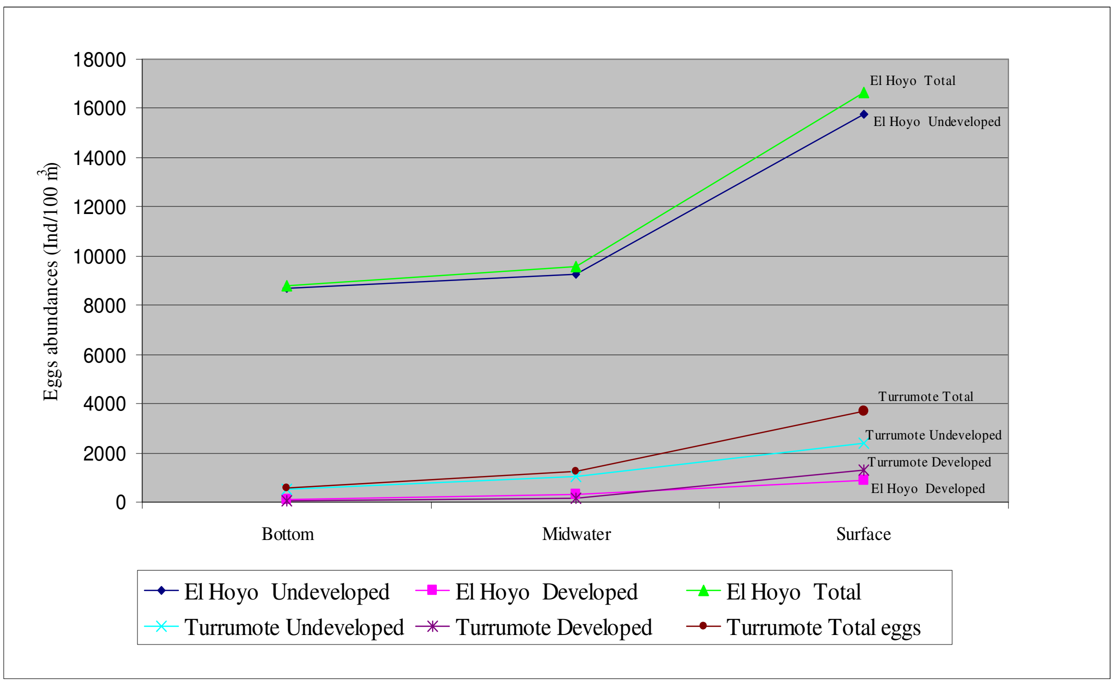


Figure 47. Vertical egg abundances obtained by diving tows at “El Hoyo” and Turrumote Key on March 12, 1998, during the third full moon of the year.

Table 5 and Figure 48 summarize the spatial and temporal patterns of total egg abundance expressed in eggs/100 m^3 by sampling station and date. The specific moon phase at each sampling cruise is shown in Table 5. These illustrate that at station 5 (near the shelf edge) and at the station 6 (neritic/oceanic interphase) egg abundances were higher than at the station 4, while station 3 (inshore) showed the highest abundances during the study. Station 3 is a nearshore passage between the En Medio, Enrique, Turrumote and Media Luna reefs and could be acting as a collector from local and upstream reproduction sources, as water flow in this area is channeled by these reefs and the shoreline. Station 4 is outside these four reefs and the funnel effect would not be expected at this location. Thus, the increased abundances at Station 3 can be explained as an upstream funnel accumulation effect, instead of a shoreward dispersal of propagules from the near shelfedge region. García et al. (1995) documented egg and larval abundances at Guayanilla, just upstream of La Parguera, as being an order of magnitude greater than those found off La Parguera (Ramírez 2000 and this study). The higher level of egg abundances observed at station 3 on April 3, when very low westerly water translations were recorded (Figure 48, week in purple), can be explained by mixed factors, the funnel accumulation effect, combined with retention processes and the accumulation of local nearshore reef species reproducing at that time.

The total mean abundances by station (Table 5) reflect a very low level of dispersal offshore, supporting the theory that under the oceanographic conditions prevailing during this study, connectivity between the neritic and oceanic realms is very

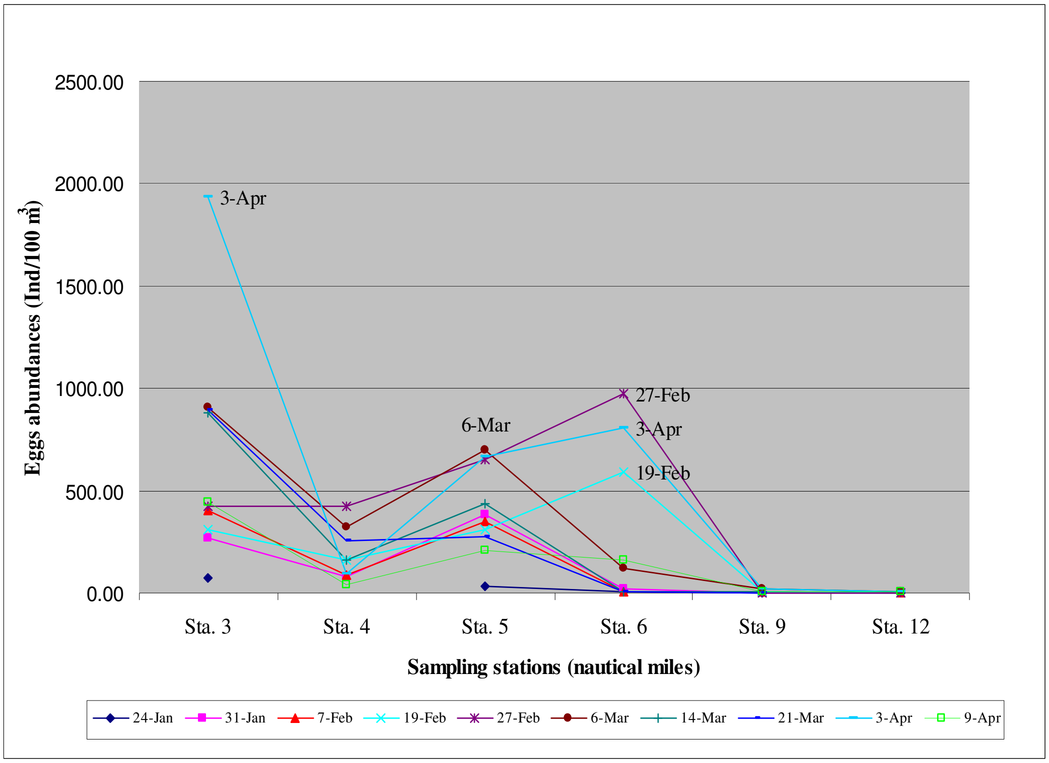


Figure 48. Total egg abundance by sampling station and dates, for La Parguera, Puerto Rico in 1997.

Table No. 5. Spatial and temporal pattern in 1997 of eggs abundance by sampling station and by date for La Parguera, Puerto Rico. (-) and (+) corresponds to days before or after the moon phase. Abundances are expressed in eggs/100 m^3.

Moon Phase	Full ○	Half ○	New ●	- 2 d ○	Quarter ○	- 2 d ●	+ 3 d ●	- 2 d ○	- 4 d ●	+ 4 d ●	Mean
Date	24-Jan	31-Jan	7-Feb	19-Feb	27-Feb	6-Mar	14-Mar	21-Mar	3-Apr	10-Apr	Abund.
Distance (nm)											
3	73.37	270.86	404.35	308.59	426.16	910.51	881.46	891.38	1936.00	442.11	**654.48**
4	--	78.49	85.31	162.40	423.53	320.43	163.92	252.59	95.45	41.79	**175.79**
5	36.18	381.85	352.80	308.36	651.81	701.23	438.55	273.40	665.25	211.06	**402.05**
6	9.14	21.78	8.79	593.04	974.48	123.20	4.65	9.27	803.67	161.87	**270.99**
9	2.65	2.99	3.70	6.68	3.28	17.14	6.21	1.27	18.94	8.40	**7.13**
12	1.90	7.38	1.05	1.88	1.96	7.98	--	--	5.46	7.36	**4.37**
Mean	Westerly coastal upcurrents replenishing propagules and west dispersion of local spawned pelagic eggs								Retention	Reversion	
Abund.	**24.65**	**127.22**	**142.67**	**230.16**	**413.54**	**346.75**	**249.13**	**237.99**	**587.46**	**145.43**	

limited, and that there existed an effective barrier for pelagic eggs dispersal during most of the time. However, the same cannot be concluded for long distance dispersal to the west, at least based on the current meter data and the NLOM simulation results. At times, the predicted surface currents would have resulted in long distance transport of eggs away from Puerto Rico. Nevertheless, the majority of the time the oceanic surface currents contoured the southwest shelf of Puerto Rico, and entered the Mona Channel. Thus, during those times, offshore hydrodynamic conditions could again be acting as a barrier to egg dispersal. Rojas (2000) did not include egg analyses in her October 2000 study. But McMillan (per. comm.) found no genetic differences among adults in the western (Mona Passage) and southern (La Parguera) red hind spawning aggregations. The low egg abundances obtained on January 24 indicate that little spawning occurred at that time, either at upcurrent sources or at the red hind spawnings grounds near the shelf edge.

To determine if any increment in egg abundance was related to red hind spawning, the temporal/spatial abundance patterns were analyzed by station and by date for the 0.9 mm to 1.0 mm diameter egg range (Figures 49 and 50).

The temporal abundance distribution pattern of potential red hind eggs showed a normal distribution, with three more or less distinctive peaks that might be attributed to specific spawning events from different species. These were examined by station (Figure 50) to determine if any might be related to the red hind spawning aggregation near the shelf edge.

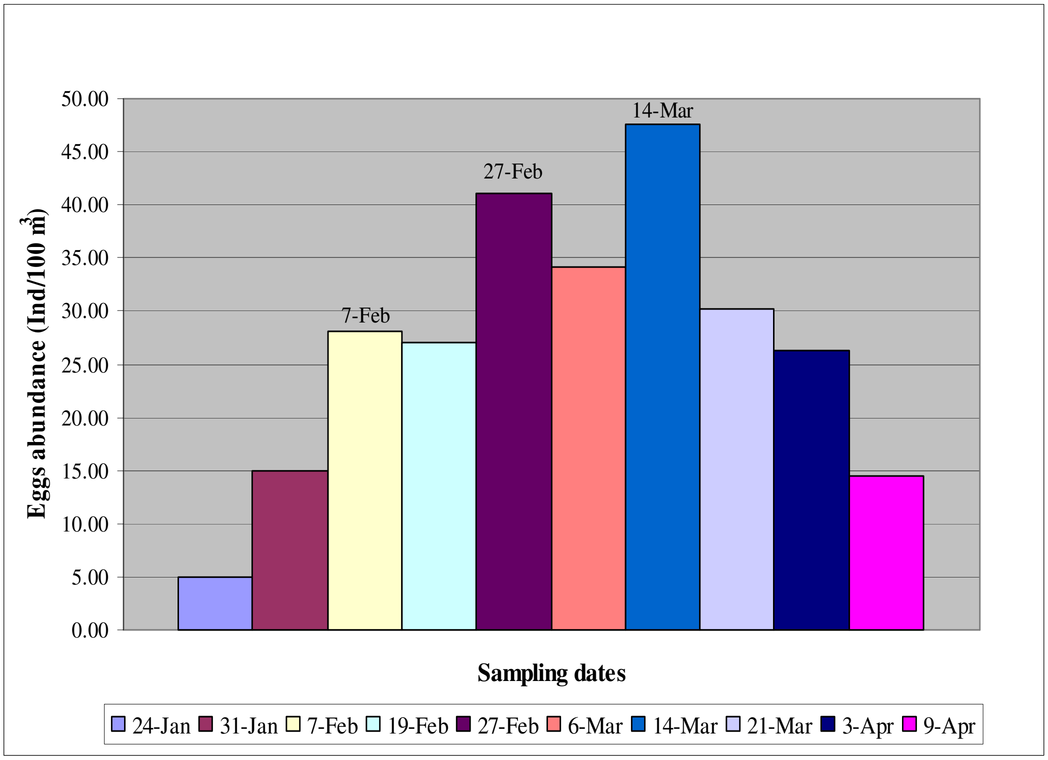


Figure 49. Total mean egg abundances off La Parguera, Puerto Rico, by sampling date for the 0.9 mm to 1.0 mm diameter range. Abundances presented are for eggs/100 m^3.

There were two sampling cruises that showed some probability of representing the import of red hind mass spawnings in 1997, the first on February 19 (two days prior to the second full moon of the year) and the second on February 27 (five days after the second full moon of the year). At these dates higher abundances where found simultaneously at the stations 4 and 6, decreasing at the station 3 (Figure 50), as should be expected if spawning were occurring near the shelfedge off La Parguera and further upstream to the east. This also occurs just after the period when water temperature dropped to levels appropriate for red hind spawning and subsequent egg and larval development (see Figures 19 and 20). It is thus suggested that spawning occurred at the time of the second full moon (February 22), with actual spawning spread out over a period of days starting before and ending after that specific day. Coincidently, the February 22 full moon occurred the day prior to a lunar apogee. Colin and Clavijo (1988) noted significant shelfedge spawning off La Parguera occurring at the start of ebb tide and suggested that this timing may be for the benefit of adults rather than eggs and larvae, and that the change of tidal currents provides an environmental cue to initiate the act of spawning. Having an environmental cue that an entire population can sense simultaneously has the advantage of synchronizing the spawning activities of the population.

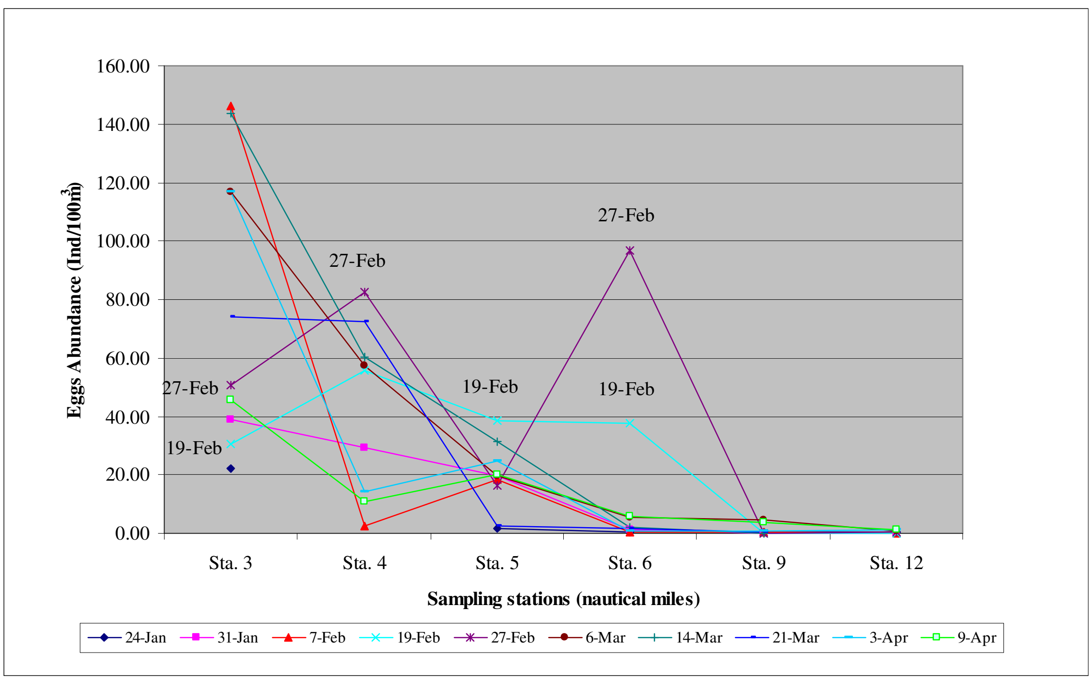


Figure 50. Egg abundance of potential red hind (0.9 mm to 1.0 mm diameter), off La Parguera, Puerto Rico, distributed by sampling stations and by sampling dates.

2.2 Larvae Distribution and Abundances.

2.2 1. Spatial and temporal variation of ichthyoplankton abundance.

A total of 92 taxa, including five orders and 91 families of larval fishes were identified from a collection of 20,499 individuals. Phylogeny and taxonomic nomenclature followed Eschmeyer (1990). Individuals were further classified as pre-flexion or post-flexion larvae (Table 6), and as reef (R) or oceanic (O). Pre-flexion stage larvae represented 89.8 % of the total collection, whereas the remaining 10.2 % were flexion and post-flexion stage larvae. Of the pre-flexion larvae, 22.8 % were not identifiable to any level due to their lack of morphological differentiation. The majority of these were newly hatched free embryos. The remaining 77.2 % of pre-flexion larvae were identified either to Family or to Order level. Taxa grouped at the order level consisted of the Clupeiformes, Lophiformes, Lampriformes, Pleuronectiformes and Tetraodontiformes. All post-flexion larvae were identified to family level.

Total larval abundance declined across the neritic-oceanic gradient (Figure 51), but this reflected primarily the trend for pre-flexion larvae; post-flexion larval abundance was low and almost stable across the entire gradient. Post-flexion larvae ranged from 41.1 ind/100m^3 at station 12 and 99.41 ind/100m^3 at station 5, while pre-flexion ranged from 972.41 at station 3 to 216.85 ind/100m^3 at station12 (Table 7). High predation pressure and other natural mortality and low local offshore dispersal are factors that may yield the decline of pre-flexion larvae with distance from shore. Ramírez (2000) off La Parguera and Rojas (2002) in the Mona Passage also found similar declining patterns. Ramírez (2000) concluded that the shelfedge represents a transition point between the neritic and oceanic regimes for larval fishes. This conclusion was supported by González (2002) who worked at the shelfedge in Guayanilla Bay, Puerto Rico. The results of the present study (Figures 52, 53) suggest a more offshore transition point if we select the point where larvae are split roughly between reef and oceanic species. This transition point occurred for pre-flexion larvae at the station 9 (Figure 52), and at the station 12 for post-flexion larvae (Figure 53).

This definition characterizes oceanic and neritic realms, but does not reflect dispersal. The big drop of total and pre-flexion larvae, comes between the stations 5 and 6 (Figure 51), while the post-flexion larvae trend shows a major abundance peak at the station 5, decreasing at both sides (onshore and offshore). Post-flexion larval distribution is in great extent modeled by larval behavior, which can exhibit substantial interspecific variability (Mora and Sale, 2002).

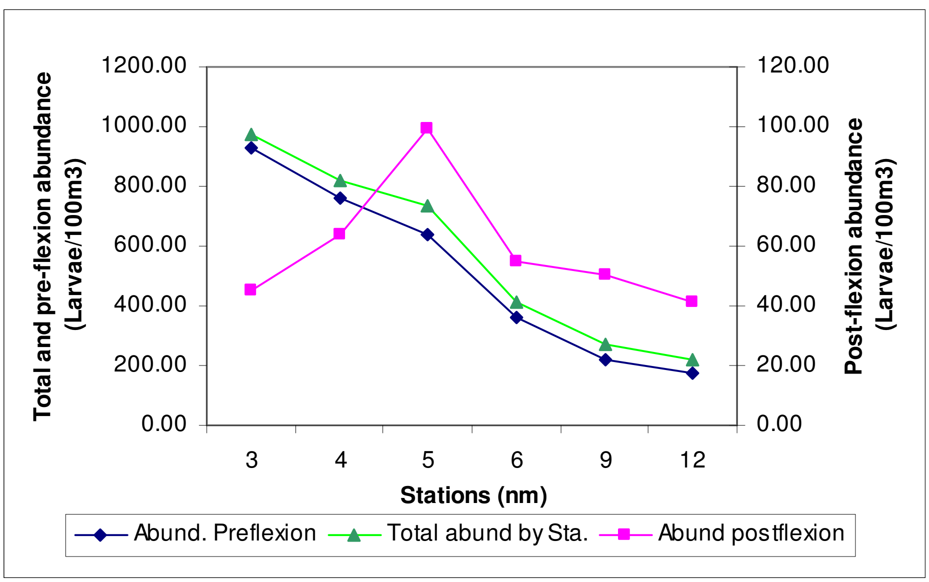


Figure 51. Total larval, pre-flexion and post-flexion abundance in a neritic-oceanic gradient off La Parguera, Puerto Rico, during a red hind spawning event. (Jan 24-April 9,1997). Secondary axis refers to Post-flexion larvae.

Table 6 : Taxonomic composition, temporal mean abundance of pre-flexion and post-flexion fish larvae, and total study abundance by family during a red hind spawning event off La Parguera during 1997.

FAMILY	Larvae Type	24-Jan			31-Jan			7-Feb			19-Feb			27-Feb			6-Mar			14-Mar			21-Mar			3-Apr			9-Apr			Total	% of total
	Reef (R)	Mean Abund		Total	Mean Abund		Total	Mean Abund		Total	Mean Abund		Total	Mean Abund		Total	Mean Abund		Total	Mean Abund		Total	Mean Abund		Total	Mean Abund		Total	Mean Abund		Total	Study	Study
	Oceanic (O)	Pre	Post		Pre	Post		Pre	Post		Pre	Post		Pre	Post		Pre	Post		Pre	Post		Pre	Post		Pre	Post		Pre	Post		Abundance	abund.
Congridae	R																												0.026		0.026	0.026	0.004
Muraenidae	R								0.069	0.069							0.028		0.028													0.097	0.016
Ophichthidae	R																0.050		0.050				0.032		0.032				0.028		0.028	0.110	0.018
Nemichthyidae	R	0.090		0.090				0.017		0.017				0.052		0.052										0.096		0.096				0.255	0.042
Clupeiformes	R	0.447		0.447	0.362		0.362	0.099		0.099	2.727		2.727				1.764		1.764	0.609		0.609	0.170		0.170	0.146		0.146				6.323	1.045
Clupeidae	R	0.052	0.052	0.105	0.985	0.014	0.999	0.034	0.026	0.060	0.168		0.168	0.449		0.449	0.388		0.388	0.299	0.039	0.338	0.863		0.863	4.385	1.001	5.386	4.523	1.951	6.473	15.230	2.517
Engraulidae	R	1.069	0.243	1.312	1.006	0.106	1.112	3.603	0.033	3.636	4.656	0.183	4.839	1.021		1.021	2.120	0.201	2.321	5.747	0.599	6.346	3.222	0.067	3.289	6.795	0.374	7.169	4.402	0.186	4.588	35.632	5.890
Gonostomatidae	O	0.015	0.112	0.127	0.457	0.645	1.102	0.119	0.120	0.239	0.506	0.118	0.624	0.371	0.060	0.430	0.531	0.121	0.652	0.300		0.300	0.250	0.144	0.394	0.255	0.611	0.866	0.582	0.369	0.951	5.684	0.940
Sternoptychidae	O																									0.024		0.024				0.024	0.004
Phosichthyidae	O				0.053	0.047	0.100	0.088	0.011	0.099		0.025	0.025	0.016		0.016	0.074	0.107	0.181							0.331	0.066	0.397	0.103	0.070	0.173	0.990	0.164
Stomiidae	O																	0.025	0.025													0.025	0.004
Chauliodontidae	O	0.034		0.034																	0.092	0.092					0.021	0.021				0.147	0.024
Astronesthidae	O											0.022	0.022											0.018	0.018	0.024	0.041	0.064				0.104	0.017
Melanostomiidae	O								0.008	0.008	0.049	0.021	0.070					0.028	0.028		0.021	0.021							0.093	0.025	0.118	0.245	0.041
Notosudidae	O										0.045		0.045														0.033	0.033		0.025	0.025	0.104	0.017
Synodontidae	R														0.014	0.014	0.025		0.025													0.038	0.006
Neoscopelidae	O				0.021	0.008	0.029	0.026		0.026																						0.055	0.009
Myctophidae	O	3.217	0.507	3.724	16.197	1.068	17.265	3.863	1.655	5.518	3.043	0.683	3.726	3.214	0.338	3.552	3.922	0.740	4.662	0.949	0.273	1.223	1.230	0.150	1.380	5.916	0.521	6.437	3.088	0.655	3.743	51.230	8.468
Paralepididae	O	0.095	0.024	0.119	0.017	0.016	0.033	0.056		0.056	0.174		0.174	0.166		0.166	0.077	0.030	0.108		0.041	0.041	0.137		0.137	0.039	0.036	0.075	0.045	0.029	0.074	0.983	0.162
Evermannellidae	O							0.040		0.040																			0.046	0.045	0.091	0.131	0.022
Scoperlarchidae	O																									0.088		0.088				0.088	0.014
Bregmacerotidae	O							0.008		0.008							0.050	0.025	0.074							0.024		0.024				0.107	0.018
Ophidiidae	R	0.014		0.014	0.032	0.008	0.040		0.019	0.019							0.030	0.029	0.059	0.043		0.043	0.049		0.049	0.044		0.044				0.269	0.044
Batrachoididae	R							0.008		0.008																						0.008	0.001
Bythitidae	R				0.257	0.356	0.613	0.310	0.154	0.464							0.061	0.161	0.222	0.036	0.237	0.273	0.028	0.028	0.057		0.265	0.265	0.058	0.282	0.340	2.232	0.369
Lophiformes	O				0.008		0.008	0.061		0.061																						0.069	0.011
Carapidae	R																									0.064		0.064				0.064	0.011
Antennariidae	O																			0.113		0.113										0.113	0.019
Ogcocephalidae	R				0.009		0.009																									0.009	0.001
Gobiesocidae	R		0.014	0.014	0.357	0.051	0.408	0.088	0.024	0.112	0.108	0.023	0.130	0.070	0.037	0.107		0.133	0.133	0.022		0.022	0.058		0.058				0.061	0.118	0.179	1.163	0.192
Callionymidae	R	0.498	0.013	0.511		0.044	0.044		0.026	0.026	1.404	0.298	1.701	0.848	0.110	0.958	0.393	0.285	0.678	2.308	0.124	2.432	2.406	0.247	2.653	0.135	0.106	0.242	2.330	0.616	2.946	12.191	2.015
Atherinidae	R																0.086		0.086	0.041		0.041	0.029		0.029				0.397	0.029	0.426	0.582	0.096
Belonidae	R	0.000	0.010	0.010	0.021	0.021	0.042		0.025	0.025					0.182	0.182		0.033	0.033					0.026	0.026	0.021	0.021	0.042		0.182	0.182	0.541	0.089
Hemiramphidae	R		0.052	0.052		0.120	0.120	0.022	0.017	0.039	0.092		0.092	0.066	0.066	0.132	0.037	0.090	0.127	0.077	0.152	0.229				0.091		0.091	0.068	0.124	0.192	1.074	0.178
Exocoetidae	O	0.024	0.024	0.047		0.009	0.009											0.043	0.043		0.036	0.036		0.028	0.028		0.019	0.019				0.183	0.030
Lampriformes	O																						0.016		0.016							0.016	0.003
Trachipteridae	O				0.024		0.024																									0.024	0.004
Holocentridae	R	0.047		0.047				0.046		0.046	0.068		0.068	0.051		0.051	0.105		0.105	0.450	0.113	0.564	0.127	0.035	0.161	0.249	0.015	0.265	0.177		0.177	1.484	0.245
Aulostomidae	R	0.038		0.038																												0.038	0.006
Fistularidae	R																0.043		0.043							0.075		0.075				0.118	0.019
Syngnathidae	R		0.087	0.087	0.030	0.671	0.701	0.026	0.301	0.327		0.088	0.088		0.066	0.066		0.294	0.294		0.274	0.274		0.308	0.308		0.161	0.161	0.061	0.369	0.430	2.736	0.452
Dactylopteridae	R	0.018		0.018	0.115	0.021	0.136	0.042		0.042																			0.032		0.032	0.228	0.038
Scorpaenidae	R	0.049		0.049	0.010	0.017	0.026	0.031		0.031	0.049		0.049	0.040	0.024	0.065		0.049	0.049		0.022	0.022	0.014	0.014	0.027	0.042	0.021	0.063	0.058	0.025	0.083	0.464	0.077
Triglidae	R													0.014		0.014	0.025		0.025	0.022		0.022										0.060	0.010
Serranidae	R	1.783	0.255	2.038	0.464	0.009	0.473	0.818	0.098	0.916	0.184	0.071	0.255	1.759	0.141	1.900	0.685	0.053	0.737	0.730		0.730	0.490	0.152	0.642	0.945	0.079	1.024	0.773	0.981	1.754	10.469	1.730
Grammistidae	R					0.006	0.006																									0.006	0.001
Priacanthidae	R	0.060		0.060																0.022		0.022							0.095		0.095	0.177	0.029
Apogonidae	R		0.078	0.078					0.115	0.115		0.022	0.022		0.140	0.140				0.167	0.224	0.391		0.036	0.036	0.161	0.093	0.254	0.190	0.521	0.711	1.749	0.289
Malacanthidae	R																									0.025		0.025				0.025	0.004
Echeneidae	R				0.067		0.067																0.068		0.068							0.135	0.022
Carangidae	R	0.251	0.036	0.287	0.150		0.150	0.185	0.019	0.205	0.051	0.069	0.120	0.106	0.014	0.119	0.508	0.028	0.537	0.592	0.048	0.640	0.595	0.015	0.610	0.467	0.088	0.555	0.846	0.169	1.015	4.237	0.700
Coryphaenidae	O	0.018		0.018	0.164	0.021	0.184	0.100	0.047	0.147					0.026	0.026	0.199	0.025	0.224	0.041	0.041	0.083	0.131		0.131	0.142		0.142	0.029	0.082	0.111	1.067	0.176
Bramidae	O				0.031	0.016	0.046		0.023	0.023		0.024	0.024																			0.093	0.015
Lutjanidae	R	0.166	0.057	0.223	0.560	0.040	0.600	0.010	0.025	0.034	0.030		0.030	0.159	0.060	0.219	0.919	0.025	0.945	2.227	0.210	2.438	0.909	0.075	0.984	2.213	0.222	2.435	3.602	0.763	4.365	12.272	2.028
Gerreidae	R		0.018	0.018				0.012	0.052	0.064	0.599	0.218	0.817	0.199	0.461	0.659	0.061	0.121	0.182	0.022	0.191	0.213	0.463	0.598	1.062	0.230	0.384	0.614		0.206	0.206	3.835	0.634
Haemulidae	R	0.316	0.043	0.359	0.490	0.198	0.688	0.590		0.590				0.260	0.069	0.329	0.731	0.136	0.867	1.318	0.150	1.467	1.595	0.138	1.733	1.482	0.197	1.679	1.076	0.131	1.207	8.919	1.474
Sparidae	R	0.192	0.166	0.358					0.031	0.031				0.076	0.066	0.142	0.122	0.139	0.261	0.026	0.041	0.067	0.319	0.100	0.419	0.302	0.139	0.440	0.029	0.029	0.058	1.775	0.293
Sciaenidae	R	0.150		0.150	0.164		0.164	0.076		0.076	0.197	0.105	0.302	1.278		1.278	0.917	0.024	0.942	0.581		0.581	1.115		1.115	0.546	0.050	0.596	0.584		0.584	5.787	0.957
Mullidae	R	0.024		0.024	0.042		0.042	0.063		0.063	0.117	0.240	0.358	0.807		0.807	0.485	0.047	0.532	0.155		0.155	0.961	0.155	1.116	0.241	0.040	0.281	0.336	0.087	0.424	3.800	0.628
Kyphosidae	R							0.019		0.019				0.013		0.013				0.072		0.072				0.045		0.045				0.150	0.025
Chaetodontidae	R	0.037	0.056	0.093							0.065		0.065	0.016		0.016	0.028		0.028				0.030		0.030		0.019	0.019		0.045	0.045	0.296	0.049
Pomacanthidae	R	0.019		0.019				0.008		0.008	0.030	0.024	0.054		0.024	0.024							0.033	0.019	0.051	0.032	0.021	0.053	0.089		0.089	0.298	0.049
Pomacentridae	R	0.529	0.201	0.731	3.802		3.802	5.901		5.901	2.316	0.024	2.340	4.001	0.024	4.025	1.952	0.082	2.034	5.126		5.126	4.662	0.088	4.750	3.476	0.045	3.521	12.078	0.268	12.345	44.575	7.368
Mugilidae	R	0.027		0.027				0.009	0.010	0.019	0.929		0.929	0.136		0.136	0.000	0.090	0.090	0.104	0.021	0.124	0.040	0.065	0.105	0.022		0.022	0.029	0.029	0.058	1.510	0.250

Table 6 (Cont.) : Taxonomic composition, temporal mean abundance of pre-flexion and post-flexion fish larvae, and total study abundance by family during a red hind spawning event off La Parguera during 1997.

FAMILY	Larvae Type Reef (R) Oceanic (O)	24-Jan Mean Abund Pre	24-Jan Mean Abund Post	24-Jan Total	31-Jan Mean Abund Pre	31-Jan Mean Abund Post	31-Jan Total	7-Feb Mean Abund Pre	7-Feb Mean Abund Post	7-Feb Total	19-Feb Mean Abund Pre	19-Feb Mean Abund Post	19-Feb Total	27-Feb Mean Abund Pre	27-Feb Mean Abund Post	27-Feb Total
Sphyraenidae	R	0.255	0.019	0.274	0.237	0.009	0.246	0.257	0.035	0.292	0.414	0.072	0.486	0.575		0.575
Polynemidae	R															
Labridae	R	0.617	0.245	0.863	0.176	0.110	0.285	0.458	0.131	0.589	0.373	0.188	0.561	0.572	0.124	0.696
Scaridae	R	0.640	0.292	0.933	0.117	0.119	0.235	0.051	0.328	0.379	0.143	0.129	0.272	0.792	0.143	0.935
Opistognathidae	R	0.077		0.077	0.008		0.008	0.061	0.099	0.160				0.010		0.010
Dactyloscopidae	R													0.679	0.112	0.790
Tripterygiidae	R	2.865	1.529	4.394	8.303	1.357	9.660	4.668	0.486	5.154	8.727	0.335	9.062	9.047	0.197	9.244
Chaenopsidae	R															
Labrisomidae	R		0.010	0.010					0.074	0.074				1.202	0.395	1.597
Chaenopsidae	R			0.000											0.053	0.053
Blenniidae	R	0.577	0.010	0.587	0.436	0.062	0.498	0.138		0.138	0.068	0.058	0.127	0.754		0.754
Eleotridae	R								0.074	0.074				0.049	0.060	0.109
Gobiidae	R	7.073	0.533	7.606	6.657	0.190	6.847	1.219	0.315	1.534	6.624	0.598	7.222	6.336	0.074	6.410
Microdesmidae	R	0.052	0.098	0.151	0.198		0.198	0.204	0.025	0.229	0.470	0.068	0.538	0.787		0.787
Acanthuridae	R	0.504	0.022	0.525		0.047	0.047	0.046	0.092	0.138	0.540		0.540	0.114	0.095	0.209
Siganidae	R		0.018	0.018												
Gempylidae	O				0.208	0.110	0.317	0.028	0.016	0.044	0.021		0.021		0.030	0.030
Trichiuridae	O															
Scombridae	O	0.135	0.034	0.168	2.096	0.101	2.196	0.856	0.020	0.876	0.030		0.030	0.417	0.013	0.430
Nomeidae	O	0.022		0.022	0.616	0.008	0.623	0.402	0.083	0.484	0.070	0.046	0.116	0.171	0.016	0.188
Tetragonuridae	O															
Pleuronectiformes	R	0.258		0.258	0.261		0.261	0.169		0.169	0.577		0.577	0.744		0.744
Achiridae	R	0.063	0.025	0.088	0.006		0.006	0.025		0.025						
Bothidae	R					0.008	0.008		0.080	0.080	0.024		0.024	0.132	0.016	0.148
Paralichthyidae	R	0.052		0.052				0.008		0.008						
Balistidae	R	0.214		0.214												
Monacanthidae	R	0.057	0.040	0.097												
Ostracidae	R															
Tetraodontiformes	R	1.218		1.218	1.535		1.535	0.836		0.836	0.355		0.355	0.437		0.437
Tetraodontidae	R	0.046		0.046				0.040		0.040	0.093		0.093	0.037	0.024	0.061
Diodontidae	R	0.015	0.061	0.076	0.062		0.062									
Molidae	O															
Unidentified		10.995		10.995	14.657		14.657	9.802		9.802	11.170		11.170	19.963		19.963
Total		35.015	4.987	40.003	61.463	5.632	67.095	35.646	4.764	40.410	47.304	3.752	51.055	58.005	3.273	61.278

FAMILY	6-Mar Mean Abund Pre	6-Mar Mean Abund Post	6-Mar Total	14-Mar Mean Abund Pre	14-Mar Mean Abund Post	14-Mar Total	21-Mar Mean Abund Pre	21-Mar Mean Abund Post	21-Mar Total	3-Apr Mean Abund Pre	3-Apr Mean Abund Post	3-Apr Total	9-Apr Mean Abund Pre	9-Apr Mean Abund Post	9-Apr Total	Total Study Abundance	% of total Study abund.
Sphyraenidae	0.340	0.055	0.395	0.477		0.477	0.224	0.207	0.432	0.535	0.079	0.614	0.225	0.077	0.302	4.093	0.677
Polynemidae				0.109	0.113	0.222										0.222	0.037
Labridae	0.966	0.052	1.017	1.073	0.021	1.094	1.936	0.185	2.120	3.455	0.208	3.663	0.368	0.412	0.780	11.668	1.929
Scaridae	0.028	0.188	0.217		0.051	0.051	0.125	0.099	0.224	0.125	0.142	0.268	0.555	0.563	1.118	4.632	0.766
Opistognathidae	0.288	0.087	0.375				0.111		0.111	0.077	0.052	0.129		0.065	0.065	0.934	0.154
Dactyloscopidae	0.047	0.085	0.133	0.036	0.036	0.072	0.193	0.233	0.426	0.132	0.049	0.181				1.602	0.265
Tripterygiidae	4.773	0.388	5.161	10.431	0.949	11.379	9.348	1.007	10.355	6.166	1.558	7.725	7.084	1.717	8.801	80.934	13.377
Chaenopsidae	0.085		0.085	0.122		0.122				0.026		0.026				0.234	0.039
Labrisomidae	0.043	0.030	0.073	0.041		0.041								0.028	0.028	1.823	0.301
Chaenopsidae					0.202	0.202		0.113	0.113		0.186	0.186				0.555	0.092
Blenniidae	0.544		0.544	0.285		0.285	3.190	0.059	3.249	0.610	0.026	0.636	0.311	0.169	0.480	7.298	1.206
Eleotridae	0.043	0.039	0.082		0.022	0.022			0.000	0.024	0.040	0.064	0.072	0.147	0.219	0.570	0.094
Gobiidae	2.535	0.684	3.218	7.929	0.239	8.168	8.716	0.294	9.010	8.811	1.937	10.748	8.948	2.268	11.217	71.979	11.897
Microdesmidae	0.516	0.102	0.618	1.067	0.113	1.180	0.545	0.057	0.602	0.626	0.544	1.170	1.124	0.302	1.427	6.899	1.140
Acanthuridae	0.096	0.035	0.131	0.127	0.000	0.127	0.353	0.014	0.366	0.246	0.047	0.293	0.320	0.024	0.344	2.721	0.450
Siganidae																0.018	0.003
Gempylidae	0.025	0.025	0.050	0.048	0.022	0.070	0.031	0.031	0.062	0.074	0.043	0.117	0.024		0.024	0.735	0.121
Trichiuridae	0.029		0.029						0.000							0.029	0.005
Scombridae	0.598	0.064	0.662	0.607		0.607	0.457		0.457	0.810	0.114	0.924	0.589	0.077	0.666	7.017	1.160
Nomeidae	0.245		0.245	0.102	0.022	0.124								0.114	0.114	1.916	0.317
Tetragonuridae			0.000	0.460	0.039	0.498				0.089		0.089	0.053		0.053	0.641	0.106
Pleuronectiformes	0.208		0.208	0.301		0.301	0.037		0.037	0.023		0.023	0.140		0.140	2.717	0.449
Achiridae		0.050	0.050				0.017		0.017	0.047		0.047	0.046		0.046	0.279	0.046
Bothidae	0.039	0.025	0.065				0.018	0.018	0.035		0.065	0.065	0.184	0.072	0.256	0.682	0.113
Paralichthyidae														0.028	0.028	0.089	0.015
Balistidae		0.054	0.054				0.015	0.019	0.033	0.058		0.058				0.359	0.059
Monacanthidae	0.047		0.047	0.036	0.026	0.062	0.111	0.018	0.129	0.131	0.025	0.155	0.086	0.051	0.136	0.626	0.104
Ostracidae	0.037		0.037	0.095		0.095				0.022		0.022				0.154	0.025
Tetraodontiformes	0.266		0.266	0.752		0.752	1.124		1.124	1.155		1.155	2.782		2.782	10.460	1.729
Tetraodontidae	0.229	0.050	0.278	0.136		0.136	0.164		0.164	0.827	0.038	0.865	0.523	0.028	0.551	2.236	0.370
Diodontidae													0.029		0.029	0.168	0.028
Molidae	0.028		0.028	0.022		0.022										0.050	0.008
Unidentified	9.547		9.547	16.657		16.657	20.373		20.373	11.801		11.801	13.231		13.231	138.195	22.842
Total	38.018	5.176	43.194	63.113	4.803	67.916	67.131	4.856	71.987	65.042	9.842	74.884	72.629	14.555	87.185	605.006	100.00

Table 7: Taxonomic composition and total abundance (larvae/100m^3) by station, for pre-flexion and post-flexion larvae collected off La Parguera, Puerto Rico, during Jan-24 to Apr-9 (1997)

Station	Larval	3M	3M	4M	4M	5M	5M	6M	6M	9M	9M	12M	12M
	Type	Total	% of	Total	% of	Total	% of	Total	% of	Total	% of	Total	% of
FAMILY	Reef (R)	Abund.	Total	Abund.	Total	Abund.	Total	Abund.	Total	Abund.	Total	Abund.	Total
Preflexion	Oceanic (O)												
Congridae	R							0.16	0.04				
Muraenidae	R									0.17	0.08		
Ophichthyidae	R							0.25	0.07	0.37	0.17		
Nemichthyidae	R			0.30	0.04			0.31	0.09	0.29	0.13	0.54	0.31
Clupeiformes	R	7.21	0.78	15.89	2.10	12.53	1.96	0.62	0.17				
Clupeidae	R	29.09	3.13	31.81	4.20	5.46	0.86	4.68	1.30	0.18	0.08		
Engraulidae	R	137.22	14.78	42.45	5.60	10.52	1.65	0.98	0.27	0.42	0.19	0.14	0.08
Gonostomatidae	O			1.01	0.13	0.51	0.08	3.89	1.08	5.80	2.62	8.52	4.85
Sternoptychidae	O											0.14	0.08
Phosichthyidae	O							2.28	0.63	0.52	0.23	1.20	0.68
Chauliodontidae	O									0.17	0.08		
Astronesthidae	O											0.14	0.08
Melanostomidae	O											0.85	0.48
Notosudidae	O									0.27	0.12		
Synodontidae	R							0.15	0.04				
Neoscopelidae	O			0.15	0.02					0.12	0.06		
Myctophidae	O	14.13	1.52	7.62	1.00	28.12	4.41	45.23	12.53	72.78	32.82	93.19	53.02
Paralepididae	O							0.94	0.26	2.02	0.91	1.65	0.94
Evermanelidae	O									0.24	0.11	0.28	0.16
Scoperlarchidae	O							0.38	0.11			0.14	0.08
Bregmacerotidae	O							0.35	0.10			0.14	0.08
Ophidiidae	R	0.18	0.02					0.33	0.09	0.53	0.24	0.13	0.07
Batrachoididae	R							0.05	0.01				
Bythitidae	R			0.93	0.12	3.14	0.49			0.36	0.16		
Lophiformes	O					0.37	0.06	0.05	0.01				
Carapidae	R							0.38	0.11				
Antennariidae	O							0.23	0.06	0.34	0.15		
Ogcocephalidae	R							0.05	0.01				
Gobiesocidae	R	0.99	0.11	2.17	0.29	1.23	0.19			0.11	0.05		
Callionymidae	R	53.41	5.75	0.80	0.11	0.23	0.04	0.75	0.21	0.84	0.38	0.69	0.39
Atherinidae	R	2.58	0.28	0.52	0.07							0.15	0.09
Belonidae	R									0.12	0.06	0.13	0.07
Hemiramphidae	R			1.33	0.18	0.40	0.06	0.78	0.22			0.13	0.07
Exocoetidae	O											0.12	0.07
Lampriformes	O							0.08	0.02				
Trachipterydae	O											0.15	0.08
Holocentridae	R			0.15	0.02	0.89	0.14	1.24	0.34	4.17	1.88	0.86	0.49
Aulostomidae	R							0.19	0.05				
Fistularidae	R					0.50	0.08	0.13	0.03				
Syngnathidae	R	0.36	0.04	0.34	0.04								
Dactylopteridae	R					0.19	0.03	0.05	0.01	0.62	0.28	0.37	0.21
Scorpaenidae	R					0.38	0.06	0.13	0.04	0.69	0.31	0.50	0.28
Triglidae	R							0.15	0.04	0.11	0.05	0.08	0.05
Serranidae	R	10.85	1.17	13.80	1.82	8.50	1.33	7.23	2.00	5.92	2.67	2.29	1.31
Priacanthidae	R							0.30	0.08	0.41	0.19	0.27	0.15
Apogonidae	R	1.57	0.17					0.49	0.14	0.88	0.40		
Malacanthidae	R			0.15	0.02								
Echeneidae	R	0.34	0.04							0.27	0.12	0.14	0.08
Carangidae	R	3.14	0.34	1.45	0.19	2.38	0.37	2.97	0.82	8.13	3.67	2.91	1.65
Coryphaenidae	O			0.99	0.13	0.66	0.10	0.97	0.27	0.93	0.42	1.21	0.69
Bramidae	O							0.18	0.05				
Lutjanidae	R	7.49	0.81	26.28	3.47	16.81	2.63	6.59	1.83	2.88	1.30	1.26	0.71
Gerreidae	R	0.64	0.07	4.02	0.53	4.01	0.63	0.12	0.03	0.24	0.11		
Haemulidae	R	19.91	2.14	18.02	2.38	2.11	0.33	1.65	0.46	2.08	0.94	0.13	0.07
Sparidae	R	3.05	0.33	1.04	0.14	1.45	0.23			0.13	0.06		
Sciaenidae	R	18.93	2.04	4.20	0.55	4.05	0.63	3.90	1.08	0.37	0.17		
Mullidae	R	0.17	0.02	2.67	0.35	10.43	1.63	1.04	0.29	3.02	1.36	0.64	0.36
Kyphosidae	R	0.63	0.07					0.12	0.03			0.08	0.05
Chaetodontidae	R	0.17	0.02					0.33	0.09	0.14	0.07	0.34	0.20

Table 7 (Cont.): Taxonomic composition and total abundance (larvae/100m^3) by station, for pre-flexion and post-flexion larvae collected off La Parguera, Puerto Rico, during Jan-24 to Apr-9 (1997)

Pomacanthidae	R							0.32	0.09	0.35	0.16	0.53	0.30
Pomacentridae	R	55.18	5.94	81.83	10.79	88.32	13.85	22.42	6.21	3.11	1.40	0.77	0.44
Mugilidae	R	4.92	0.53	0.96	0.13	0.55	0.09	0.65	0.18	0.52	0.23		
Sphyraenidae	R	1.32	0.14	3.63	0.48	3.09	0.48	4.12	1.14	5.98	2.70	2.32	1.32
Polynemidae	R	0.54	0.06										
Labridae	R	9.83	1.06	11.30	1.49	10.08	1.58	13.14	3.64	9.26	4.17	2.54	1.45
Scaridae	R			0.40	0.05			1.82	0.50	8.70	3.92	3.77	2.14
Opistognathidae	R	1.13	0.12	0.72	0.09	1.06	0.17	0.38	0.11			0.12	0.07
Dactyloscopidae	R			0.28	0.04	6.09	0.95						
Tripterygiidae	R	84.14	9.06	136.75	18.04	142.36	22.32	33.93	9.40	4.06	1.83	0.74	0.42
Chaenopsidae	R					2.31	0.36						
Labrisomidae	R	0.46	0.05			6.13	0.96	1.09	0.30				
Blenniidae	R	12.11	1.30	18.10	2.39	6.75	1.06	0.20	0.05	0.26	0.12		
Eleotridae	R					0.60	0.09	0.20	0.05			0.24	0.14
Gobiidae	R	154.95	16.69	85.33	11.25	62.39	9.78	52.08	14.42	2.73	1.23	6.59	3.75
Microdesmidae	R	15.85	1.71	10.81	1.43	3.89	0.61	0.78	0.22	0.28	0.13	0.08	0.05
Acanthuridae	R	0.26	0.03	0.13	0.02	0.17	0.03	3.65	1.01	2.63	1.18	6.26	3.56
Gempylidae	O							0.20	0.05	1.52	0.69	0.95	0.54
Trichiuridae	O			0.17	0.02								
Scombridae	O	2.11	0.23	2.43	0.32	1.82	0.29	9.26	2.56	10.45	4.71	12.30	7.00
Nomeidae	O			0.90	0.12	2.29	0.36	2.03	0.56	2.85	1.29	1.39	0.79
Tetragonuridae	O			0.15	0.02	2.15	0.34	0.26	0.07	0.31	0.14	0.29	0.16
Pleuronectiformes	R	8.55	0.92	2.12	0.28	2.68	0.42	1.01	0.28	0.84	0.38	0.33	0.19
Achiridae	R					0.15	0.02	0.47	0.13	0.25	0.11	0.28	0.16
Bothidae	R							0.79	0.22	0.53	0.24	1.05	0.60
Paralichthyidae	R	0.26	0.03					0.05	0.01				
Balistidae	R	1.20	0.13					0.12	0.03	0.17	0.08		
Monacanthidae	R	1.56	0.17	0.13	0.02	0.35	0.06	0.21	0.06	0.25	0.11		
Ostracidae	R	0.13	0.01	0.22	0.03	0.36	0.06	0.12	0.03				
Tetraodontiformes	R	16.32	1.76	14.02	1.85	22.79	3.57	5.14	1.42	1.11	0.50	0.28	0.16
Tetraodontidae	R	1.05	0.11	5.21	0.69	3.66	0.57	0.65	0.18	1.17	0.53	0.40	0.23
Diodontidae	R	0.13	0.01	0.17	0.02			0.08	0.02	0.25	0.11		
Molidae	O									0.11	0.05	0.17	0.09
Unidentified		244.39	26.32	204.28	26.95	152.89	23.97	115.27	31.92	47.42	21.38	14.86	8.46
Abund. Preflexion		928.41	100.00	758.12	100.00	637.77	100.00	361.10	100.00	221.78	100.00	175.76	100.00

Station	**Larval**	**3M**	**3M**	**4M**	**4M**	**5M**	**5M**	**6M**	**6M**	**9M**	**9M**	**12M**	**12M**
	Type	**Total**	**% of**	**Total**	**% of**	**Total**	**% of**	**Total**	**% of**	**Total**	**% of**	**Total**	**% of**
FAMILY	**Reef (R)**	**Abund.**	**Total**	**Abund.**	**Total**	**Abund.**	**Total**	**Abund.**	**Total**	**Abund.**	**Total**	**Abund.**	**Total**
Postflexion	**Oceanic (O)**												
Muraenidae	R									0.27	0.55	0.14	0.34
Clupeidae	R	0.86	1.91	16.65	26.08	0.65	0.66	0.24	0.44				
Engraulidae	R	4.76	10.60	3.92	6.15	2.06	2.08	0.21	0.39				
Gonostomatidae	R			0.31	0.49	0.19	0.19	2.09	3.83	3.83	7.63	7.12	17.33
Phosichthyidae	R							0.52	0.95	0.62	1.23	0.81	1.97
Stomiidae	O							0.15	0.27				
Chauliodontidae	O							0.59	1.08				
Astronesthidae	O									0.19	0.38	0.28	0.67
Melanostomiidae	O							0.05	0.09	0.43	0.85	0.12	0.30
Notosudidae	O									0.35	0.70		
Synodontidae	R											0.08	0.20
Neoscopelidae	O							0.05	0.09				
Myctophidae	O	0.55	1.22	1.50	2.35	3.34	3.36	6.93	12.68	11.92	23.76	14.53	35.37
Paralepididae	O							0.48	0.87	0.28	0.56	0.23	0.57
Evermanellidae	O											0.27	0.65
Bregmacerotidae	O							0.15	0.27				
Ophidiidae	R			0.17	0.27			0.16	0.30				
Bythitidae	R			2.39	3.75	5.99	6.03	0.14	0.27				
Gobiesocidae	R			0.35	0.54	1.41	1.42	0.53	0.97				
Callionymidae	R	3.69	8.22			0.68	0.69	3.60	6.59	1.98	3.95	0.95	2.30
Atherinidae	R							0.18	0.32				
Belonidae	R	1.21	2.71	0.20	0.31	1.37	1.38	0.05	0.09	0.12	0.25		

Table 7 (Cont.): Taxonomic composition and total abundance (larvae/100m^3) by station, for pre-flexion and post-flexion larvae collected off La Parguera, Puerto Rico, during Jan-24 to Apr-9 (1997)

Hemiramphidae	R	0.70	1.57	1.09	1.70	0.86	0.86	0.10	0.17	0.60	1.20		
Exocoetidae	O					0.66	0.67	0.17	0.31			0.12	0.29
Holocentridae	R	0.39	0.86			0.18	0.18	0.09	0.16	0.18	0.36		
Syngnathidae	R	6.56	14.62	5.48	8.58	1.63	1.64	0.97	1.78	0.23	0.47		
Dactylopteridae	R									0.12	0.25		
Scorpaenidae	R							0.59	1.08	0.41	0.81		
Serranidae	R					1.43	1.44	5.80	10.62	2.76	5.50	0.62	1.52
Grammistidae	R							0.04	0.07	0.00	0.00		
Apogonidae	R	1.00	2.22	0.40	0.62	1.07	1.08	1.88	3.45	2.57	5.12	0.13	0.31
Carangidae	R	0.34	0.76			0.19	0.20	0.47	0.86	1.58	3.15	0.23	0.56
Coryphaenidae	O			0.49	0.77			0.16	0.29	0.33	0.66	0.44	1.07
Bramidae	O							0.09	0.17	0.14	0.29	0.14	0.34
Lutjanidae	R	2.06	4.58	1.01	1.58	2.62	2.64	1.41	2.59	1.26	2.51	0.15	0.37
Gerreidae	R	1.52	3.38	4.11	6.43	5.23	5.27	1.55	2.84	0.10	0.21	0.09	0.22
Haemulidae	R	1.71	3.81	2.46	3.86	0.93	0.94	0.27	0.50	0.56	1.12	0.10	0.24
Sparidae	R	2.29	5.10	0.83	1.29	0.54	0.54	0.21	0.39				
Sciaenidae	R			0.13	0.21	0.80	0.80	0.14	0.27				
Mullidae	R	0.19	0.43	0.37	0.58	2.19	2.21	0.31	0.57	0.10	0.20		
Chaetodontidae	R							0.40	0.73			0.27	0.65
Pomacanthidae	R							0.13	0.23	0.38	0.76		
Pomacentridae	R					1.67	1.68	1.06	1.94	0.78	1.55	0.50	1.22
Mugilidae	R	0.26	0.57	0.34	0.53	0.19	0.19	0.22	0.41	0.10	0.21		
Sphyraenidae	R			0.47	0.73	1.09	1.09	0.87	1.58	0.53	1.05	0.15	0.36
Polynemidae	R	0.57	1.26										
Labridae	R					0.61	0.61	2.04	3.73	2.60	5.19	4.35	10.58
Scaridae	R	0.65	1.45					3.42	6.25	5.05	10.07	2.77	6.73
Opistognathidae	R	0.88	1.97	0.17	0.27	0.76	0.76						
Dactyloscopidae	R			0.30	0.46	2.36	2.37						
Tripterygiidae	R	2.03	4.51	11.60	18.18	39.00	39.23	1.25	2.28				
Labrisomidae	R	0.17	0.38	0.63	0.99	2.18	2.20	0.05	0.09	0.18	0.36		
Chaenopsidae	R			1.28	2.00	1.74	1.75						
Blenniidae	R	0.36	0.81	0.53	0.83	1.16	1.16	0.19	0.34				
Eleotridae	R			0.17	0.27	0.71	0.71	0.31	0.56	0.71	1.42	0.37	0.91
Gobiidae	R	10.52	23.45	3.89	6.10	10.87	10.93	11.16	20.43	3.48	6.93	1.33	3.25
Microdesmidae	R	1.45	3.24	2.11	3.31	3.05	3.06	0.87	1.59	0.10	0.20		
Acanthuridae	R							0.28	0.51	1.25	2.49	0.69	1.69
Siganidae	R											0.09	0.22
Gempylidae	O							0.15	0.28	0.48	0.96	0.97	2.35
Scombridae	O	0.17	0.37					0.40	0.73	1.11	2.21	0.83	2.03
Nomeidae	O							0.19	0.34	0.53	1.05	1.00	2.43
Tetragonuridae	O			0.19	0.30								
Achiridae	R							0.42	0.77				
Bothidae	R							0.44	0.81	0.50	0.99	0.75	1.82
Paralichthyidae	R							0.17	0.31				
Balistidae	R									0.26	0.53	0.15	0.37
Monacanthidae	R			0.15	0.23					0.63	1.25	0.09	0.22
Tetraodontidae	R			0.13	0.21			0.17	0.31	0.54	1.08		
Diodontidae	R							0.08	0.14			0.23	0.56
Abund postflexion		44.88	100.00	63.83	100.00	99.41	100.00	54.62	100.00	50.17	100.00	41.10	100.00
Total abund by Sta.		973.29		821.95		737.18		415.72		271.95		216.85	

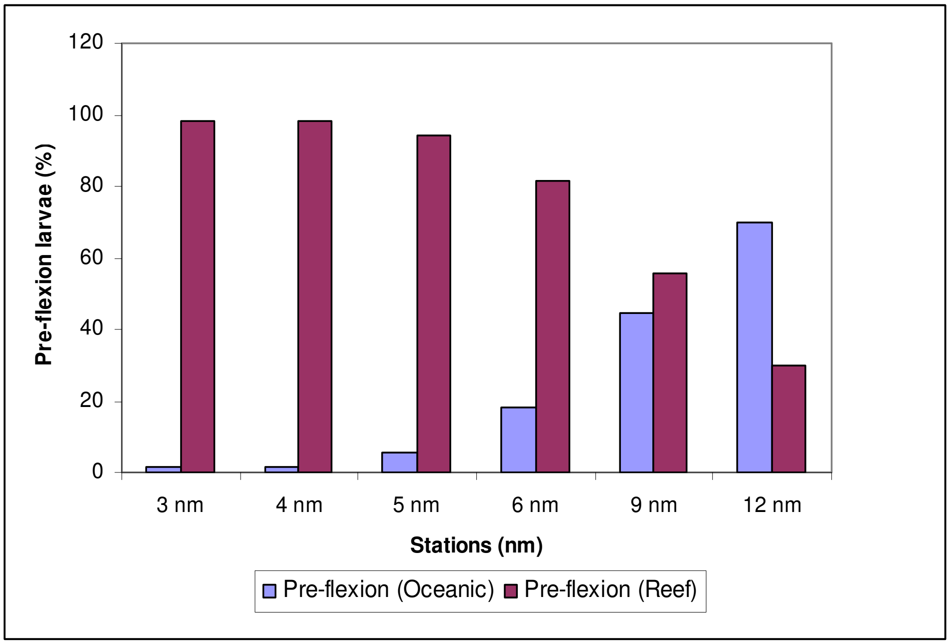


Figure 52. Proportion of pre-flexion reef and oceanic fish larvae across a neritic-oceanic gradient off La Parguera, Puerto Rico, during Jan 24-April 9, 1997.

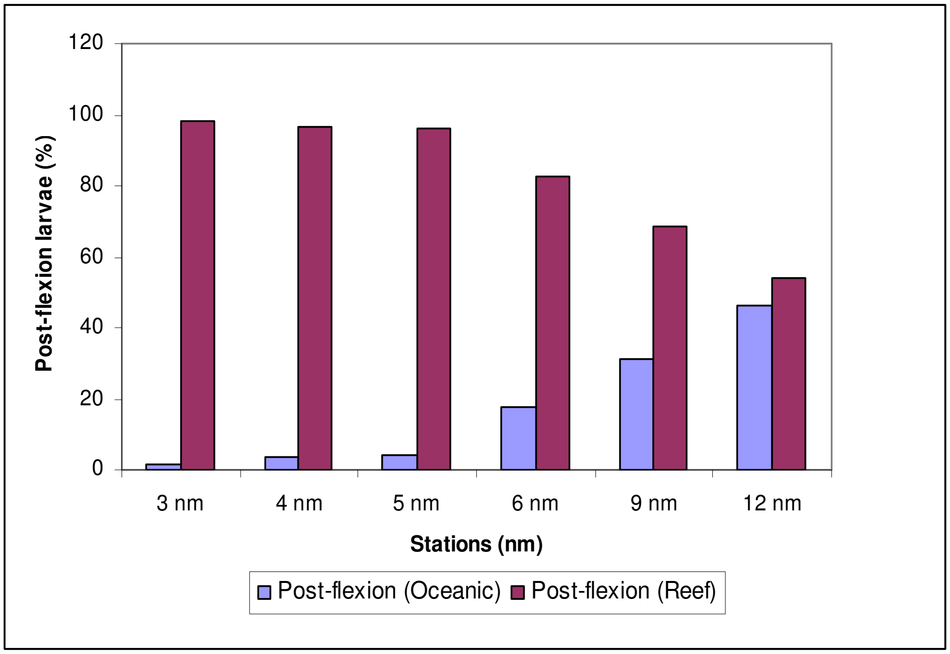


Figure 53. Proportion of post-flexion reef and oceanic fish larvae across a neritic-oceanic gradient off La Parguera, Puerto Rico, during Jan 24-April 9, 1997.

To identify if this declining neritic-oceanic abundance pattern was temporally consistent during the red hind spawning season, total abundances by sampling date and stations (Appendix I) were plotted in Figure 54. On January 24 the highest values occurred at stations 3 and 5, decreasing thereafter. On January 31 (at the first full moon of 1997) abundance peaked at the station 4, and then continually declined before increasing again at station 12. February 7 and 19 showed generally declining abundances with some variability, possible due to upstream arrivals from previous spawnings. The most unique distribution curve occurred on February 27, where a peak was found at the stations 4 and 6. Importantly, this curve coincided with the highest chlorophyll-a abundance, suggesting the suitability of these conditions for survival of larvae at the onset of exogenous feeding. Although information is available only for the inshore-offshore transect off La Parguera, these conditions should prevail downstream to the west as well, thus enhancing the development of larvae retained near the shelf edge. On March 6, almost uniformly low larvae abundances were found until station 9, followed by a decrease at station 12.

Samples from March 14 and 21 were still collected under the westward current conditions. During these two sampling dates, only at the inshore stations 3, 4 and 5 were larvae abundant. The last two sampling dates, April 3 and 9 correspond to calm retention conditions. On April 3, there was an increase at the station 6 compared to previous dates. The last week showed an increase of larval abundances at the stations 3, 4 and 5, and an increase at station 12. At the last week larval transport could have been occurring from the western adjacent areas.

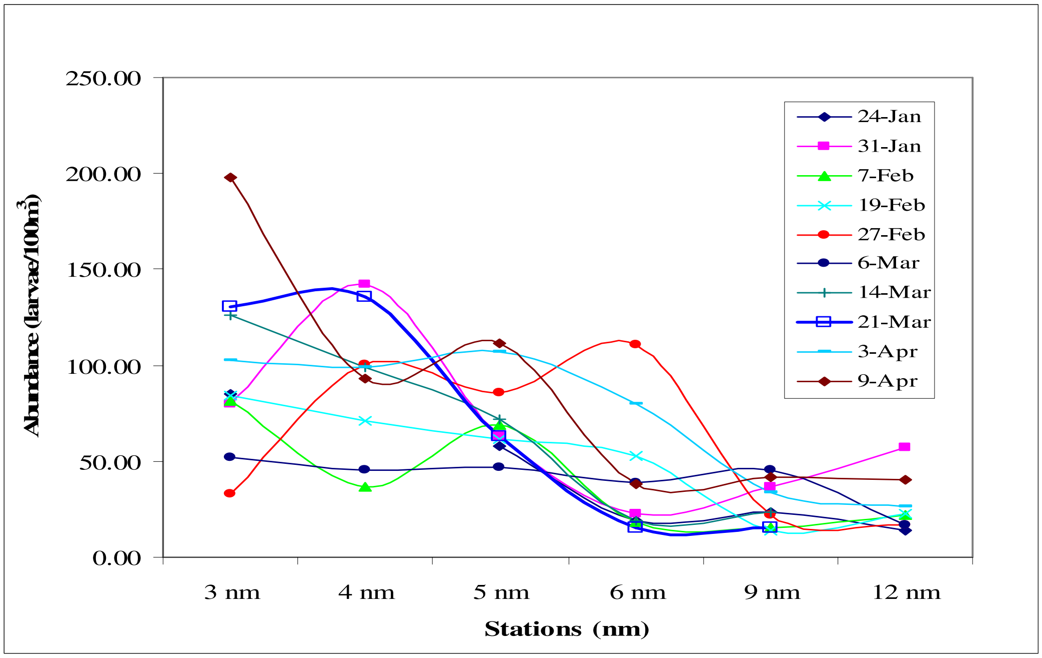


Figure 54. Temporal variation in total larval abundance by stations off La Parguera, Puerto Rico, during a red hind spawning event. (Jan 24-April 9, 1997). Abundance in (ind/100m^3).

In order to differentiate behavior among pre-flexion and post-flexion larvae under the prevailing oceanographic conditions, abundances of fish larvae by sampling date (from Table 6) were plotted (Figure 55). Increments of pre-flexion larval abundance occurred on Jan 31, Feb 27 and Mar 14. The first two increments occurred after each one of the first two full moons of the year (Jan 24, Feb 22), but the third increment occurred just after the new moon (March 10). All three increments occurred during the period when dispersive wind driven currents were prevailing over La Parguera shelf and further offshore by the north Caribbean westward currents. Pre-flexion larval abundance remained high for the remainder of the sampling period, increasing even further during the final sampling period. This sustained increase could be related to the following factors (or some subset there of): 1) spawning synchronizations with the third full moon,

2) calm currents and retention conditions that prevailed after March 23 and 3) current reversals after April 3. At that time, self-recruitment should have occurred, and probably some degree of transport from western reproduction sources may have seeded local areas. The pattern shown for post-flexion larvae, while reflecting overall low abundance, is somewhat different than that observed for pre-flexion larvae. In particular, post-flexion larvae did not show any increment of abundance on February 27, but increased a week later, on March 6. This level of abundance was then maintained until March 21, when large increments were observed through April 3 and 9. For this latter period, it appears, in a relative sense, that post-flexion larvae were responding sooner, and to a greater degree relative to pre-flexion larvae, to the change in current patterns to conditions fostering retention.

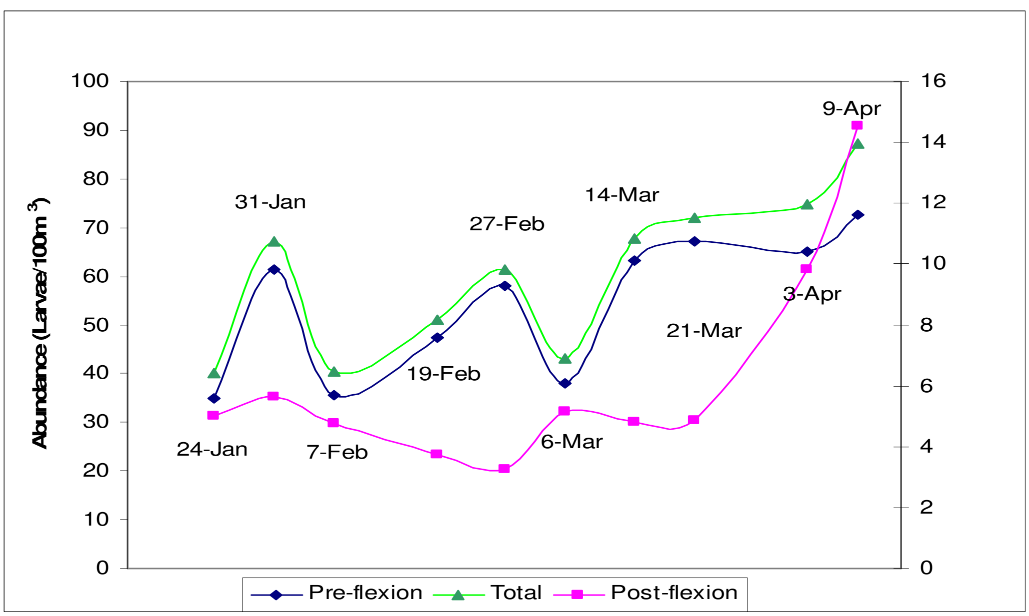


Figure 55. Temporal variation of pre-flexion, post-flexion and total overall abundances (larvae/100m^3) by sampling date, during Jan 24 to April 9 (1997) off La Parguera, Puerto Rico, through a red hind spawning event. Secondary axis refers to Post-flexion larvae abundance.

2.2 2. Taxonomic distribution and abundances.

Horizontal and vertical ichthyoplankton characterizations off La Parguera were thoroughly discussed by Ramírez (2000). Therefore, only general information plus new or different findings relative to her study will be presented here.

The most abundant family during the study was the Tripterygiidae (13.4%) followed by the Gobiidae (11.9%), Myctophidae (8.5%), Pomacentridae (7.4%), Engraulidae (5.9%), Clupeidae (2.5%), Lutjanidae (2.0%), Callionymidae (2.0%), Labridae (1.9%) and Serranidae (1.7%) (Table 8). These ten most abundant families represented more than half of all larvae collected (57.2%). In the same table are included the percent abundances of the ten most abundant families for pre-flexion larvae, post-flexion larvae, reef type larvae and oceanic type larvae. As pre-flexion larvae, the ten most abundant families represented a 51.6% of total larvae collected, while post-flexion larvae represented only 6.5%. Reef type larvae summed 50.5 % for the first ten families, but the oceanic type summed only 11.7% of total larvae collected. Tables 6 and 7 summarize the spatio-temporal taxonomic composition found during the study period. Table 6 summarizes the temporal mean abundances for pre-flexion and post-flexion larvae, total abundances and as a proportion of overall abundance by family during the study. Table 7 summarizes the spatial variation across the study. Appendix I provides more detailed information on spatial mean abundances for each sampling station and for each sampling date independently. Appendix II presents the taxonomic composition (mean abundance by family) for each station, at each sampling date.

Table 8 . First ten families with relative abundance (%) expressed by categories: Total larvae, pre-flexion larvae, post-flexion larvae, reef (R) type larvae, and oceanic (O) type larvae. Proportion (%) calculated from overall study abundance.

Family	Overall	Family	Pre-flexion	Family	Post-flexion	Family	(R)-Type	Family	(O)-Type
Tripterygiidae	13.4	Tripterygiidae	11.8	Tripterygiidae	1.6	Tripterygiidae	13.4	Myctophidae	8.5
Gobiidae	11.9	Gobiidae	10.7	Gobiidae	1.2	Gobiidae	11.9	Scombridae	1.2
Myctophidae	8.5	Myctophidae	7.4	Myctophidae	1.1	Pomacentridae	7.4	Gonostomatidae	0.9
Pomacentridae	7.4	Pomacentridae	7.2	Clupeidae	0.5	Engraulidae	5.9	Nomeidae	0.3
Engraulidae	5.9	Engraulidae	5.6	Syngnathidae	0.4	Clupeidae	2.5	Coryphaenidae	0.2
Clupeidae	2.5	Clupeidae	2.0	Gonostomatidae	0.4	Lutjanidae	2.0	Phosichtyidae	0.2
Lutjanidae	2.0	Lutjanidae	1.8	Gerreidae	0.4	Callionymidae	2.0	Paralepididae	0.2
Callionymidae	2.0	tetraodontiformes	1.7	Scaridae	0.3	Labridae	1.9	Gempylidae	0.1
Labridae	1.9	Callionymidae	1.7	Engraulidae	0.3	Serranidae	1.7	Tetragonuridae	0.1
Serranidae	1.7	Labridae	1.7	Callionymidae	0.3	tetraodontiformes	1.7	Melanostomidae	0.0
	57.2		51.6		6.5		50.5		11.7

The main difference found with Ramírez's (2000) study was the abundance of Tripterygiidae. The Tripterygiidae are very difficult to differentiate at early stages from the Blenniidae, Gobiidae, and Mycthophidae. However, although myomeres counts overlap among some tripterygids and blenniids, blenniids can be distinguished by their relative inconspicuous gas bladder, the large canine teeth of most species, short gut, and the preopercular spination of many species. Tripterygiids lack head spination, the gut extends to about mid body, and the gas bladder is prominent and they have a characteristic pigmentation. Myctophids have typical striations on the gut that facilitate identification, and gobiids have lower myomeres counts and are easier to separate. Probably Ramírez (2000) misidentified tripterygiids, since triple fin blennies are well represented in Puerto Rico coastal waters. Her most abundant taxon at neritic stations was Clupeiformes, while at 49 km (26.6 nm) offshore myctophids represented almost 60% of the larvae found. In this study myctophids were relatively more abundant closer to shore; at the station 12 (22.2 km) 50 % of the larvae found were myctophids.

At station 3 (5.6 km) the most abundant pre-flexion families were the Gobiidae (16.7%), Engraulidae (14.8%), Tripterygiidae (9.06%) and Callionymidae (5.75%) (Table 7). At station 4 (7.41 km) the Tripterygiidae (18.04%), Gobiidae (11.25%), Pomacentridae (10.79%) and Engraulidae (5.60%) dominated. From station 5 (9.27 km) the most abundant pre-flexion larvae families were the Tripterygiidae (22.32%), Pomacentridae (13.85%), Gobiidae (9.78%) and Myctophidae (4.41%). Station 6 (11.16 km) near the shelfedge represented the transition from coastal to oceanic oceanographic conditions; the most abundant pre-flexion families were Gobiidae (14.42%), Myctophidae (12.53%), Tripterygiidae (9.4%), and Pomacentridae (6.21%). At the station 9 (16.7 km) the families with the highest pre-flexion larval abundances were the Myctophidae (32.82%), Scombridae (4.71%), Labridae (4.17%) and Scaridae (3.92%). At the last station 12 (22.2 km) the most abundant families of pre-flexion larvae were Myctophidae (53.02%), Scombridae (7%), Gobiidae (3.75%) and Acanthuridae (3.56%).

The following summary describes the dispersal patterns for the most abundant families obtained in this study. These results support those obtained by Ramírez (2000), where some of the most abundant families showed specific patterns in the neritic-oceanic gradient.

•**Tripterygiids,** pre-flexion larvae, although found across the entire transect, peaked over the shelf at station 5, decreasing sharply at the offshore stations, while post-flexion larvae were absent from stations 9 and 12.

•**Gobiids,** also found over the entire transect but were more abundant at the stations 3 to 6 (over the shelf), although the greater abundance occurred at station 3.

•**Myctophids,** although were found at all stations, too, this family peaked for both pre-flexion and post-flexion larvae at the oceanic station 12.

•**Pomacentrids**, although found at all stations and their maximum occurred at station 5 (over the shelf), post-flexion larvae were absent at inshore stations 3 and 4.

•**Clupeiformes (Engraulidae and Clupeidae),** both families presented almost similar dispersal patterns. Pre-flexion Engraulidae were found at all stations, while Clupeidae were absent from station 12. As post-flexion, both families did not occur further than station 6. The highest abundance of pre-flexion and post-flexion Engraulidae larvae occurred at station 3, while Clupeidae peaked at station 4.

•**Lutjanidae,** while pre-flexion larvae were found at all stations, post-flexion larvae were limited to the offshore stations 6, 9 and 12. Peak abundances for pre-flexion larvae were observed at station 4, whereas post-flexion larvae abundance peaked at stations 9 and 12.

•**Callionymids,** peaked at station 3, but were found at all stations in lower abundances.

•**Labridae,** pre-flexion larvae were found at higher abundances at stations 3, 4, 5, 6 and 9, decreasing at station 12, while post-flexion were absent from stations 3 and 4, with maximum abundance at station 12.

•**Serranidae,** pre-flexion larvae occurred at all stations, but prevailed at inshore stations with highest abundance at station 4, while post-flexion larvae were not found at the inshore stations 3 and 4, and the abundance peak was found at station 6.

•**Scaridae,** were found to be more related to the offshore stations with peak abundances at station 9, for both pre-flexion and post-flexion larvae.

•**Acanthuridae, like Scombridae,** pre-flexion larvae were found across the transect, while post-flexion larvae where restricted to stations 6, 9 and 12 with the exception of scombrids that were also found at Station 3 in very low abundance. For both larval types, the greatest peaks were observed at station 12.

•**Gonostomatidae**, were most abundant at the stations 9 and 12, and again, myctophids, although found at all stations, had major abundances at offshore stations.

•**Syngnathidae**, were found until station 9, but peak abundances occurred at stations 3 and 4.

•**Gerreidae,** were found across all the transect, but peaked at stations 4 and 5.

These results support Ramírez's (2000) conclusion that Caribbean reef fish larvae form an assemblage concentrated within a relative narrow belt fringing both the neritic and oceanic sides of the shelfedge.

2.2 3. Spatial and temporal abundance variations of serranids, with special emphasis on the red hind (*E. guttatus*):

Representatives of the five Serranidae subfamilies (Anthinae, Liopropomatinae, Grammistinae, Serraninae and Epinephelinae) were identified during the study. Importantly, all *except* Epinephelinae were found as post-flexion stages. Ramírez (2000) reported finding post-flexion Epinephelinae at stations located 6, 10, 13, 17 and 29 km (3, 5, 7, 9 and 16 nm, respectively) from shore, but in very low abundances from 0.03 ind/100m^3 to 0.25 ind/100m^3, representing only one or two individuals per station (Ramírez pers. comm.). Although exact counts were not made at the subfamily level or lower, it was clear that the most abundant subfamily was Serraninae, which can be easily differentiated from Epinephelinae by their different morphological characteristics (Richards, 2000). Furthermore, the harlequin bass *Serranus tigrinus* was the most abundant serranid species found in both pre-flexion and post-flexion stages. This species is quite common and is known to spawn from January to March at shelfedge locations; Colin and Clavijo (1988) reported spawning from a site just east of La Parguera (between La Parguera and Guayanilla Bay). Thus, it was not surprising to find almost all early developmental stages of the species represented in the samples.

For analysis of the spatio-temporal patterns of abundance, all larvae were pooled at the family level. The abundance gradient along the neritic-oceanic transect for pre-flexion, post-flexion and total larva abundances of the Serranidae are illustrated in Figure 56. Pre-flexion serranid larvae were found in much greater abundance at inshore stations 3, 4 (peak) and 5 (Figure 56), gradually decreasing to low abundance levels at station 12. Given the relatively short duration of the pre-flexion stage and that spawning occurs over the shelf, this distribution pattern is not surprising. Post-flexion larvae showed a distribution shifted toward offshore; relatively high abundance occurred at station 6, the neritic-oceanic interface station, with abundance decreasing sharply inshore and gradually offshore.

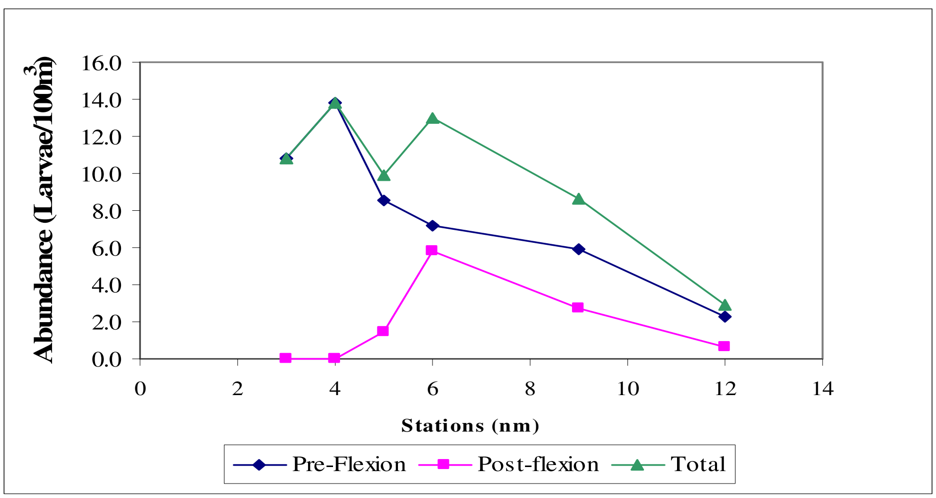


Figure 56. Spatial variation of pre-flexion, post-flexion and total abundances Serranidae larval abundance across a neritic-oceanic transect off La Parguera, Puerto Rico, during a red hind spawning event, (Jan-24 to Apr-9, 1997).

Ramírez (2000) identified three basic dispersal patterns for the La Parguera ichthyoplankton community: one mostly neritic, a widespread oceanic one, and one associated to the outer shelf and shelfedge. She placed the Serranidae under the third pattern. The present results show that serranid larvae are found in abundance over the entire shelf, as well as at the shelfedge. Only the distribution of post-flexion serranid larvae fits the classification of Ramírez (2000). However, the static picture present in the data of Ramírez (2000), or even in the data given in Figure 56 does not represent the temporal changes that occur in larval distributions. Thus, simple classifications can be misleading.

Data on the temporal and spatial abundance (i.e., by both date and station) of pre- and post-flexion serranid larvae are given in Table 9. The temporal abundance variations for pre-flexion, post-flexion and total Serranid larvae are illustrated in Figure 57. For all periods except the last, the total abundance curve reflects the dominance of pre-flexion larvae in the samples. Two distinct peaks of pre-flexion larvae occur on January 24 and February 27, respectively. These occur just after full moon and are most likely a reflection of adult spawning associated with the lunar cycle. In particular, the peak observed on February 27 (Figure 50) occurs at a time of a high abundance of potential red hind eggs as would be expected considering close temporal coupling between the egg and pre-flexion stages. This was also a time characterized by lower temperatures assumed to be necessary for red hind to spawn and also by high chlorophyll-a concentrations, which would facilitate subsequent larval feeding. That the majority of spawning is limited to the time of full moon is indicated by the sharp declines observed in the week following these abundance peaks, as larvae moved into post-flexion stage. No peak was observed with respect to the full moon in March, possibly because sampling did not occur in close proximity to that phase.

Table 9: Temporal and Spatial mean abundances, for the Serranidae family off La Parguera, Puerto Rico during a red hind spawning event (Jan24 to April-9, 1997).

Serranidae	**Date**	24-Jan	31-Jan	7-Feb	19-Feb	27-Feb	6-Mar	14-Mar	21-Mar	3-Apr	9-Apr	**Total Station Serranidae Abund.**	**% of Total Pre or Post Flexion**	**% of Study Total Serranid**
	Station	Mean Abund.	Mean Abund.	Mean Abund.	Mean Abund.	Mean Abund.	Mean Abund.	Mean Abund.	Mean Abund.	Mean Abund.	Mean Abund.			
Pre-flexion	3	2.54	0.17	2.99	0	0	0.36	1.55	0.45	1.53	1.25	10.85	22.33	18.33
	4	0	2.48	0.14	0.35	8.83	1.16	0.39	0	0.44	0	13.80	28.39	23.30
	5	5.18	0	0.30	0	0.63	0.38	0.57	0.66	0.79	0	8.50	17.50	14.36
	6	0.87	0.13	0.42	0.61	0.42	0.65	0.69	0.68	0.74	2.02	7.23	14.87	12.20
	9	0.23	0	0	0	0.29	1.37	0.45	0.66	1.56	1.36	5.92	12.18	10.00
	12	0.09	0	1.06	0.15	0.39	0	0	0	0.61	0	2.29	4.72	3.87
Total preflexion		8.92	2.78	4.91	1.11	10.56	3.92	3.65	2.45	5.67	4.64	48.60	100.00	
Post-flexion	3	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	4	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	5	1.01	0	0	0	0.42	0	0	0	0	0	1.43	13.51	2.42
	6	0.09	0.05	0.06	0.29	0.20	0.14	0	0.45	0.14	4.37	5.80	54.63	9.80
	9	0.17	0	0.26	0.00	0.14	0.17	0	0.32	0.19	1.51	2.76	25.99	4.66
	12	0	0	0.27	0.13	0.08	0	0	0	0.14	0.00	0.62	5.88	1.05
Total postflexion		1.28	0.05	0.59	0.42	0.85	0.32	0.00	0.76	0.47	5.89	10.62	100.00	
Total		10.19	2.84	5.50	1.53	11.40	4.24	3.65	3.21	6.14	10.52	59.22		100.00

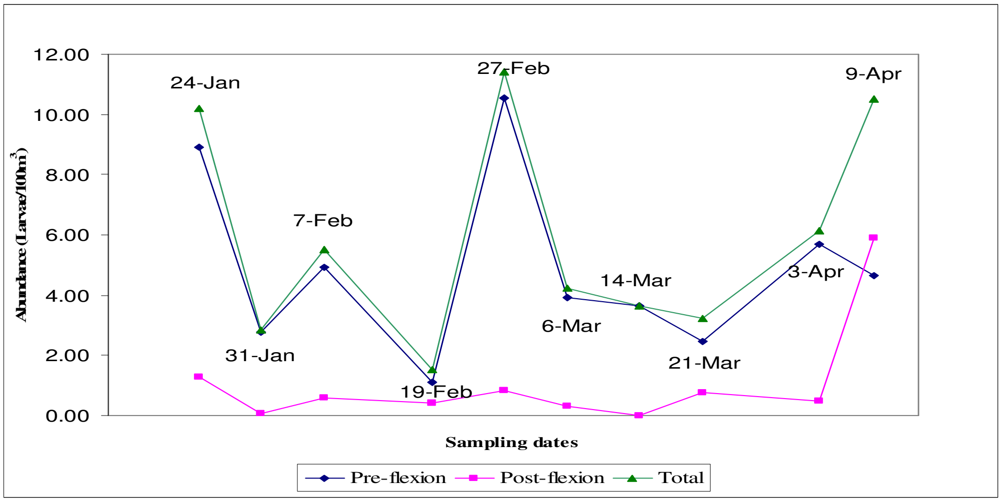


Figure 57. Temporal variation of pre-flexion, post-flexion and total overall abundances for Serranidae by sampling dates, during Jan 24 to April 9 (1997) off La Parguera, through a red hind spawning event.

The overall trend for serranid pre-flexion larvae was similar to that for all taxa (Figure 55), except at the end of the sampling period (April 9). At this time, the abundance of serranid pre-flexion larvae declined, while for all taxa combined the abundance showed a marked increase. This would suggest that spawning among serranids was declining (especially in the absence of a full moon at this time) while other, non-serranid species were increasing their reproductive activity as seasonal temperatures continued to increase. Furthermore, this decline occurred at a time when oceanographic conditions supported larval retention, again suggesting that reduced spawning itself was the major factor leading to the decline in abundance.

Post-flexion serranid larvae showed low and variable abundance until April 9 (Figure 57). At this time there was an approximate 6-fold increase in abundance. This may result from the combination of pre-flexion larvae from April 3 (a minor peak) growing into the post-flexion stage, coupled with the strong retention conditions existing at this time, which may also have brought in larvae spawned at other locations from the west. The latter may be critically important, as no similar increase in post-flexion larval abundance occurred following the two major peaks in January and February.

Figures 58 and 59 give the simultaneous temporal and spatial variations in abundance of pre-flexion and post-flexion Serranidae larvae, respectively, across the neritic-oceanic gradient. These two figures show the same trends as observed in the previous two figures showing spatial or temporal variations alone, but more clearly indicate the dynamic nature of these patterns. One the one hand, a clear shift in spatial distribution is observed between pre-flexion and post-flexion larvae. Pre-flexion larval abundances were more concentrated among stations 4, 5 and 6 with decreasing abundances from inshore to offshore (Figure 58). The two largest peaks are the ones associated with the full moons in January and February. In particular, recently-hatched pre-flexion Epinephelinae larvae were found only at station 4 (in the three replicates) on Feb-27. These patterns again suggest that early stages of Serranidae are more likely to be found over the shelf, near stations 4 and 5 during specific spawning periods, with the main spawning of red hind occurring in association with the full moon of February. Meanwhile, post-flexion larvae were more abundant at stations 6, 9 and 5 (in that rank order). These also were totally absent from stations 3 and 4 during the entire study period and only appeared at station 5 during Jan-24 and Feb-27 (Figure 59). The high abundance of post-flexion Serranidae larvae during the last sampling period of current reversal (Figure 57) was located entirely off the shelf, at Stations 6 and 9 (but did not extend to Station 12).

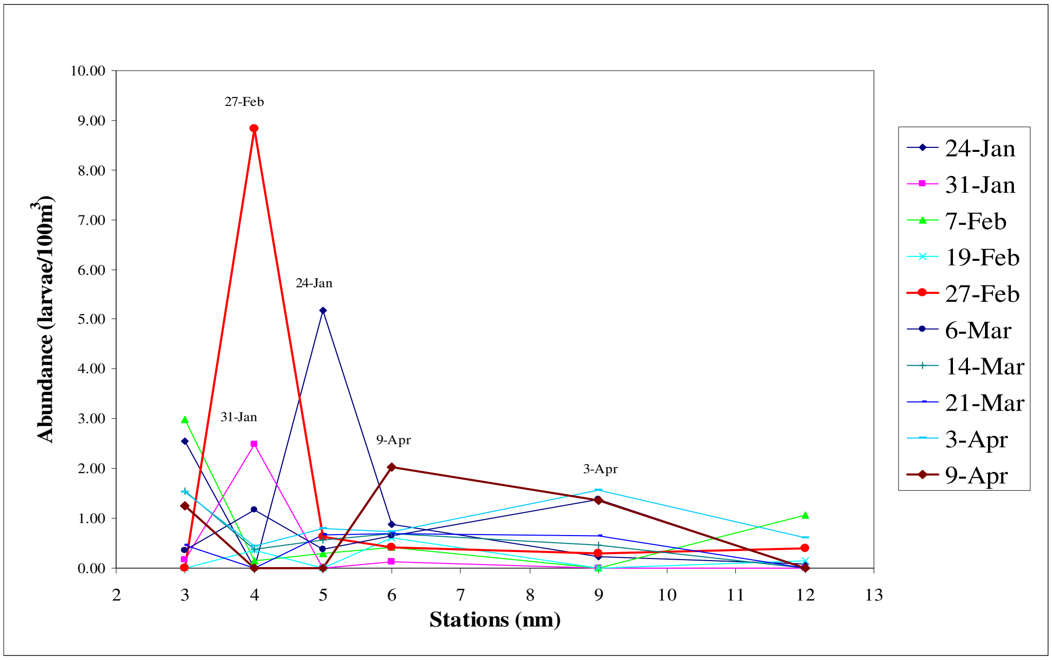


Figure 58. Temporal abundance variation for pre-flexion Serranidae larvae by stations in a neritic-oceanic transect off La Parguera, Puerto Rico, during a red hind spawning event (Jan-24 to April-9, 1997).

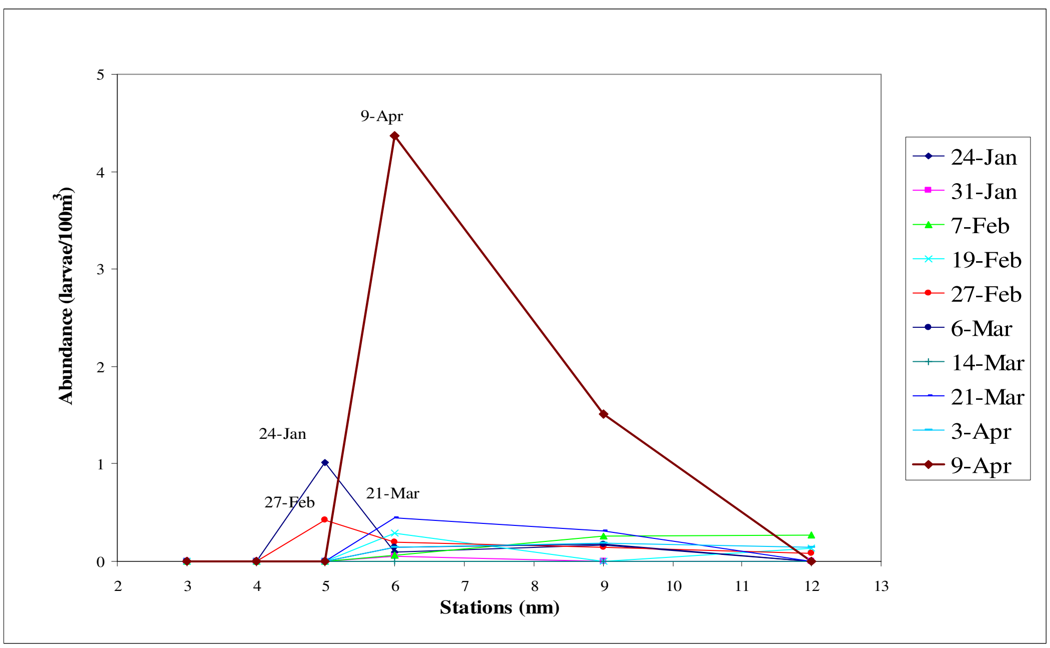


Figure 59. Temporal abundance variation for post-flexion Serranidae larvae by stations in a neritic-oceanic transect off La Parguera, Puerto Rico, during a red hind spawning event (Jan-24 to April-9, 1997).

Despite this general trend, a closer examination yields a more complex picture. For example, the peak of pre-flexion larvae on January 24 at Station 5 is coupled with a small peak in post-flexion larvae at the same station. Similarly, the large peak in post-flexion larval abundance on April 9 at Station 6 (and also Station 9) is mirrored by a minor peak in pre-flexion larvae at the same stations. The minor increase in abundance of pre-flexion larvae seen for April 3 (Figure 57) is found offshore at Station 9. Both of these instances of pre-flexion larvae offshore occurred at the time when oceanographic conditions favored retention and/or import from western locations. Furthermore, in contrast to the limited occurrence of Epinephelinae larvae (pre-flexion only), both pre-flexion and post-flexion *Serranus tigrinus* (Serraninae) were found on almost all sampling dates and in almost all stations where Serranidae were identified. Thus, while the general trend is pre-flexion larvae being inshore over the shelf and post-flexion larvae being near the shelfedge or just offshore, the actual pattern at any given time may be determined by local spawning dynamics and prevailing oceanographic conditions.

3.- Summary and Conceptual Model:

Based on the results obtained during the 1997 study of larval distributions off of La Parguera, Puerto Rico during the red hind spawning season, a hypothetical conceptual model of larval dispersal/retention was developed. Shelf currents, NLOM current simulations, oceanographic physical parameters collected from CTD casts, and results of the spatio-temporal variations in egg and larval distribution patterns were considered in creating the model.

The red hind spawning ground known as "El Hoyo" is located near the shelfedge off La Parguera. Annual spawning aggregations occur at this site during the first three months of the year. Although the red hind spawning season extends over several months, actual spawning will not occur until the desired conditions trigger the final phase of reproduction, and the spawning event will be restricted to a shorter period of time, thought to extend over two weeks. The occurrence of eggs and larvae during this study suggested that peak spawning occurred when specific conditions existed simultaneously.

The first of these is related to the temperature regime necessary for red hind spawning and larval development. In association with a persistent east-southeast wind governing a constant western alongshore current, cooling of surface waters occurred by two main processes. The first and main process was the wind-driven cooling of the surface mixed layer, starting initially over the shelf and extending downward to depth and from onshore to offshore. The second process is more theoretic and would have occurred in deeper layers. This would have consisted of a low level onshore movement of cool water governed by Ekman drift, which resulted from the strong westward surface current driven by the wind. This process might have caused the 25.5-26°C temperature strata located beneath the thermocline to impact against the insular slope and move up and onshore. The combination of these two processes resulted in a surface mixed surface layer of maximum depth, with temperatures between 25.5-26°C.

The second condition occurring at this time concerned the potential food supply. Chlorophyll-a, and therefore food sources, increased in the area (probably fertilized by the deeper cool strata and higher in nutrient concentration). Maximum values of chlorophyll-a occurred at two depths. One was at 40 m, at the interface of neritic and oceanic conditions (Station 6) extending over the shelf. This is where pre-flexion larvae, with low swimming capabilities, develop in the mixed surface layer near the shelf edge or over the shelf. The second chlorophyll-a maximum occurred at a depth related to the picnocline-halocline. These were inclined and shallower near the shelfedge, with the inclination probably related to seiching across the Caribbean basin. Fish larvae at more advanced ontogenetic stages of development, with enough swimming capabilities, can sustain their position relative to these patches (either 40 m mixed layer or the deep picnocline-halocline layer) and take advantage of the greater food sources they offer.

Egg and larval abundance and distribution patterns, temperature records, and the known spawning biology, suggested that red hind were spawning primarily during the short period surrounding the second full moon of the year, in the last week of February. During this time, both the current meter data and the NLOM models showed that a strong westerly current prevailed along the south coast of Puerto Rico. There were several consequences of this relative to the dispersal and development of red hind eggs and larvae.

First, dispersal directly offshore was practically limited. The constant western current creates an effective barrier to offshore (southern) dispersal, favoring the retention of propagules near the shelf (although with dispersal to the west). Some degree of inshore and offshore dispersal would have occurred only through the diel variability caused by tidal fluctuations. Eggs and newly hatched larvae are buoyant. Thus, they would have been transported as passive particles to the west, but where they would have continued their ontogenetic development over or near the shelf. Once enough swimming capabilities are developed, larvae can maintain their position and they could have oriented to the areas of high food availability while maintaining their position near the shelf, ultimately to undergo settlement in coastal areas.

Secondly, the strong westward current would have resulted in the rapid transport of eggs and larvae away from the spawning sites on the shelf off La Parguera. This would explain (despite evidence of spawning) why no post-flexion Epinephelinae larvae were found and only a few early pre-flexion (free-embryo) larvae were found. Several possibilities exist concerning the fate of red hind eggs and larvae advected away from the La Parguera spawning areas (Figure 60). The majority of the time, the westward, along-shelf currents bordered the southwest corner of the island and turned northward to enter the Mona Channel. This suggests that potential larval retention to west coast habitats would have been enhanced. When the oceanic currents bordering the south corner of the shelf entered the Mona Channel, similar Ekman drift processes could have occurred, helping to maintain larvae in the near-shelf area. In contrast, during periods when the strong westward currents continued movement to the west (i.e., not entering the Mona Channel) larval dispersal would have resulted in larval transport away from Puerto Rico to potential downstream locations, such as Mona Island, or potentially Hispaniola. Thus, spawning under these conditions could result in some degree of connectivity between Puerto Rico and other distant sites if surface water conditions allowed for proper larval development and suitable settlement areas were encountered. A third condition existed between these two extremes, when a coastal gyre was set up off the western shelf. Larvae entrained in such a gyre could potentially recruit either to the western shelf of Puerto Rico or to Mona Island.

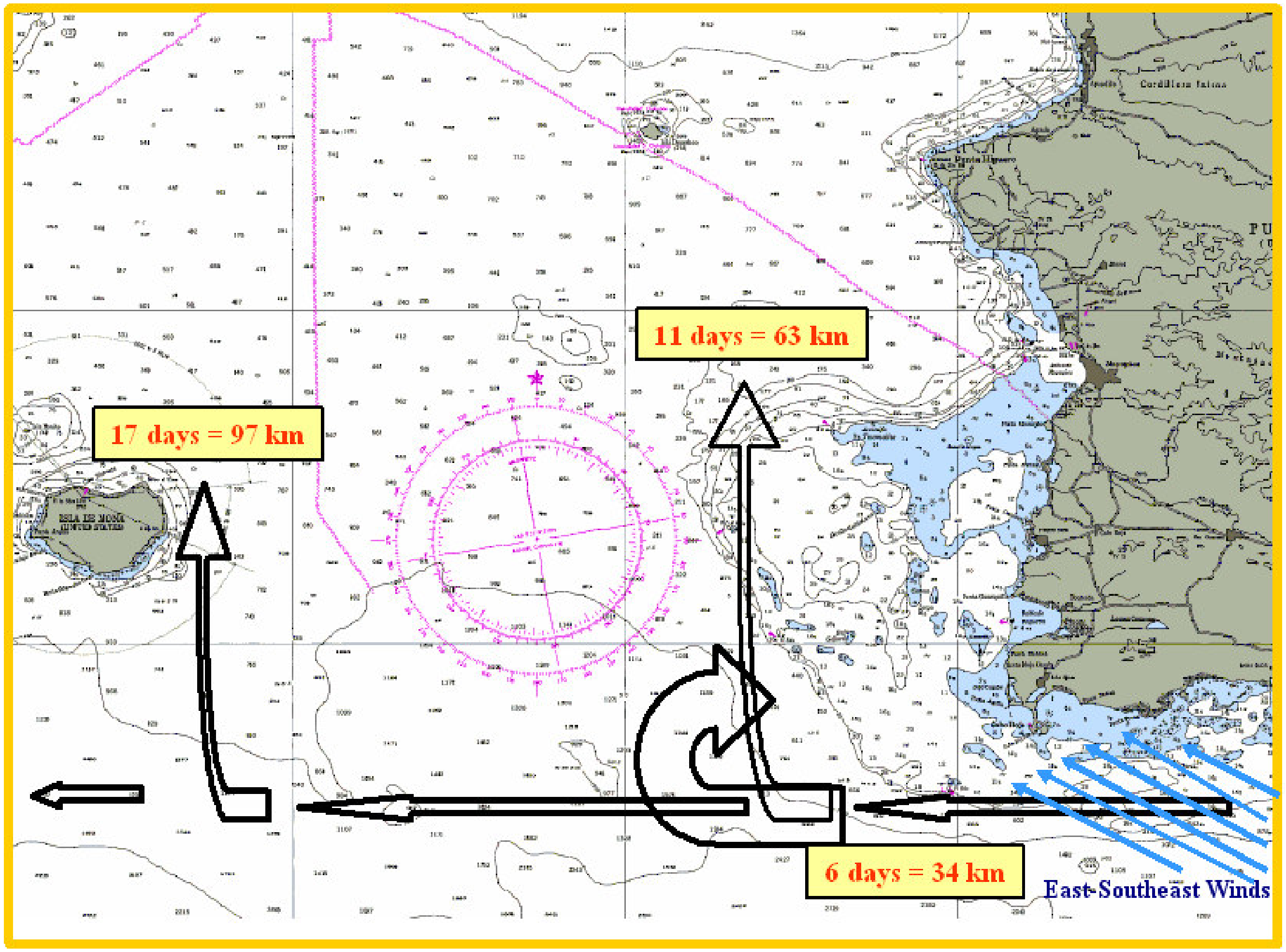


Figure 60. Summary of a conceptual model of larval dispersal/retention, during a red hind spawning event off La Parguera, Puerto Rico. Distances traveled in days are based on mean westward velocities, as measured by current meter over the La Parguera shelf from Jan-29 to Mar-6.

The potential for interchange of red hind among southwestern (La Parguera) and western populations was supported by recent genetic studies. McMillan (pers. comm.), using DNA techniques, found no differences among these populations, suggesting that a high rate of genetic interchange. This study suggests that the Mona Island red hind population would be similar as well.

In the latter part of the study there was a weakening of the east-southeast winds and a change in coastal water conditions. Slow current speeds, calm conditions and eventually current reversals were observed during the end of March and the first week of April. Under these conditions, eggs and larvae produced off La Parguera should have been retained in the area, as evidenced by the increase in post-flexion larvae, including serranids, which were found at this time (although this was now outside the red hind spawning season). Furthermore, specifically during the period of current reversals, propagules produced in areas further west and in the Mona Passage could have been transported into the La Parguera area.

Oceanographic conditions are extremely variable from year to year, both spatially and temporally, so spawning and dispersal processes occurring year to year can be quite different. In 1997, the year of this study, conditions were such that red hind spawning should not have occurred until the full moon in February and resulting eggs and larvae should have been rapidly advected away to the west. However, red hind spawning is variable and has been known undergo mass spawning in January as well. The results of this study suggests that successful local retention or dispersal of propagules spawned in the La Parguera area will depend on the match of spawning time to the prevailing oceanographic conditions. Both retention or dispersal to near or distant sites are possible.

4.- La Parguera Red Hind Management Recommendation:

Based on the declining fisheries status of the red hind, caused by extensive commercial fisheries on spawning aggregations, I strongly recommend a closure on red hind fishing at El Hoyo and other aggregation sites, for at least 60 days (starting on Jan-15 and ending Mar-15). This closure will allow a great portion of red hind to reproduce. This measure probably will allow the recuperation of El Hoyo as one of the main spawning grounds and red hind propagule sources, since during the last years the size of spawning population aggregating at that site had decreased while moving to other adjacent areas to reproduce.

CONCLUSIONS

The early ontogenetic development stages of the red hind (*Epinephelus guttatus*), obtained by artificial laboratory rearing are described and illustrated for the first time. Their early development stages were found to be very similar to other ephinephelids species previously described (i.e. *E morio* and *E. striatus*). Therefore, such similarity makes it difficult to identify to a lower level through simple microscopic visual examination.

Red hind females ovulated 48 h after induction with HCG hormone. The red hind eggs were spherical measuring 0.95 mm (± 0.03 SD), having a single oil globule. Many other species share similar egg characteristics. Thus, only potential red hind egg identification can be suggested from this study. More elaborated identification techniques are needed to identify individual eggs from large samples.

After dry fertilization, the incubation period to hatching lasted 24 h at water temperatures of 26.2-27°C. Positive buoyancy in developing eggs until hatching, and surface suspension in free embryos until 45 hours after fertilization characterized their surface vertical position in the water column. At 50 hours after fertilization the surface suspension terminated when caudal finfold broadened and pectoral fins developed. The embryonic period ended when exogenous feeding started at 70 h after fertilization, followed by an increase of larvae growth rate and when larvae swam freely.

The specific oceanographic conditions when red hind spawned at El Hoyo, off La Parguera (around the second full moon of 1997), can be summarized as:

1) the surface mixed layer varied only slightly between 25.5°C to 26°C, and the layer was at its maximum vertical extent.
2) a unique chlrophyll-a profile occurred at this time, maximum concentrations were observed over the shelf and at two depth ranges at the neritic-oceanic interface (station 6).
3) westward shelf currents circulation showed parallel to shore, were governed by strong east-southeast winds as measured with the InterOcean S4 current meter.
4) offshore oceanic circulation was also westward as characterized in the NLOM simulation illustrations.

Analysis of these data suggests several ongoing processes. Red hind spawning is synchronized with lowest water temperature (for proper egg and larval development) and high but patchy food availability at or adjacent to the spawning site (for the onset of larval exogenous feeding). The rate of feeding success may be greatly enhanced by these conditions, thus mortality due to starvation would be minimized. This synchronization may determine reproduction success for local species reproducing at this time.

The temporal and spatial egg and larval abundance were consistent with the observed oceanic and coastal conditions. Eggs and recently hatched larvae acting as passive drifters, while buoyant, were advected westward from La Parguera, while up-current sources were responsible for seeding the La Parguera area.

The westward along-shelf water movement enhanced coastal larval retention. By acting as a barrier to southward dispersal, the north Caribbean westward current thus increased retention close to the shelf. Some degree of inshore and offshore dispersal is expected only through diel variability caused by tidal fluctuations.

Oceanographic conditions are extremely variable from year to year, both spatially and temporally. Spawning and dispersal processes occurring year to year can be quite different. Therefore, high yearly recruitment variability would be expected for La Parguera new recruits, especially considering that red hind spawning is limited to 1-2 weeks/yr. But *E. guttatus* has a long reproductive life, and this variability would be compensated through multiple successive and successful spawning events. This year (1997), unusual and sustained east-southeast winds prevailed longer before weakening, retarding the period of slow current speeds, calm conditions and eventually current reversals. This affected local retention and the final self-seeding of red hind. The results of this study suggests that successful local retention or dispersal of propagules spawned in the La Parguera area will depend on the match of spawning time to the prevailing oceanographic conditions. Both retention or dispersal to near or distant sites are possible.

BIBLIOGRAPHY

Appeldoorn, R., J. Beets, J. Bohnsack, S. Bolden, D. Matos, S. Meyers, A. Rosario, Y. Sadovy & W. Tobias. 1992. Shallow water reef fish stock assessment for the U.S. Caribbean. NOAA Technical Memorandum NMFS-SEFCS-304, 70 pp.

Appeldoorn, R.S., D.A. Hensley, D.Y. Shapiro, Kioroglou and B.G. Sanderson. 1994. Egg dispersal in a Caribbean coral reef fish, *Thalasomma bifasciatum*. II- Dispersal off the reef platform. Bull. Mar. Sci. 1-22 pp.

Appeldoorn, R.S., M. Valdez-Pizzini. 1996. Survey of recreational fishing in Puerto Rico with emphasis on queen conch. Rept. To Caribb. Fish. Manage. Counc., San Juan, P.R.

Baldwin, C. C. 1990. Morphology of the larvae of American Anthiinae (Teleostei: Serranidae), with Comments on Relationships within the Subfamily. Copeia (4): 913-955.

Balon, E.K. 1985. "The theory of saltatory ontogeny and life history models revisited" in: early life histories of fishes, new developmental, ecological and evolutionary perspectives. Dr.W. Junk Publishers, Dordrecht.

Barlow, G.W. 1981. Patterns of parental investment, dispersal and size among coral-reef fishes Env. Biol. Fish. 6: 65-85

Beets, J., and A. Frielander. 1992. Stock trends and management strategies for red hind *Epinephelus guttatus*, in the U.S. Virgin Islands. Proc. Gulf Carib. Fish. Inst. 42: 66-79.

Blaxter, J. H. S. 1992. The effect of temperature on larval fishes. Netherlands Jour. of Zool. 42 (2-3): 336-357.

Bohnsack, J.A. 1996. Maintenance and recovery of reef fishery productivity. Pp. 283-313 in N.V.C. Polunin, C.M. Roberts. Reef Fisheries. Chapman &Hall, London.

Bolden, S. 1994. A summary of biological and fishery data on red hind *Epinephelus guttatus* and Coney *Cephalopholis fulva* stocks in the U.S. Virgin Islands. Report submitted to the Caribbean Fishery Management Council. 33 pp.

Borrero, M., E. González, N. Millares and T. Damas. 1978. Desarrollo embrionario y prelarval de la Biajaiba (*Lutjanus synagris,* Linné 1758). Centro de Investigaciones Pesqueras, Miramar, La Habana, Cuba. 3 (3): 1-28.

Capella, J.E. 1999. Cross-Shelf Distribution Patterns of Larval Fishes in a Caribbean Coral Reef Environment and Adjacent Oceanic Waters: Physical Oceanography Component. Dpt. of Mar. Sci., Univ. of P.R., Sea Grant Report. 6pp.

Cato, D.H. 1992. The biological contribution to the ambient noise in waters near Australia. Acoustics Aus. 20: 76-80.

Callum, M. R., N. Quinn, J.W. Tucker, and P. N. Woodward. 1995. Introduction of hatchery-reared Nassau Grouper to a Coral Reef Environment. North Amer. Jour. of Fish. Manag. 15: 159-164.

Colin, P.L. 1992. Reproduction of the Nassau grouper *Epinephelus striatus* (Pisces: Serranidae) and its relationship to environmental conditions. Environ. Biol. Fish 34: 357-377.

Colin, P.L., D.Y. Shapiro, and D. Weiler. 1987. Aspects of the reproduction of two groupers, *Epinephelus guttatus* and *E. striatus* in the West Indies. Bull. Mar. Sci. 40(2): 220-230.

Colin, P.L.. and I.E. Clavijo. 1988. Spawining activity of fishes producing pelagic eggs on a shelf edge coral reef, southwestern Puerto Rico. Bull. of Mar. Sci. 43 (2): 249-279.

Collins, L.A., J.H. Finucane, and L.E. Barger. 1980. Description of larval and juvenile red snapper, *Lutjanus campechanus*. Fishery Bulletin. 77 (4): 965-974.

Comyns. 1994. Preliminary guide to the identification of the early life history stages of lutjanid fishes on the Western Central Atlantic. NOAA Tech. Mem. NMFS-SEFSC-345, 49 p.

Coombs, S. H. 1981. A density-gradient column for determining the specific gravity of fish eggs, with particular reference to eggs of Mackerel *Scomber scombrus*. Mar. Biol. 63: 101-106.

Cowen, R. K. and L. R. Castro. 1994. Relation of coral reef larval distributions to island scale circulation around Barbados, West Indies. Bull. Mar. Sci. 54(1): 228-244.

Cowen, R.K., K.M.M. Lwiza, S. Sponaugle, C.B. París and D.B. Olson. 2000. Connectivity of marine populations: open or closed? Science 287: 857-859.

CFMC. 1996. Regulatory amendment to the fishery management plan for the reef fish fishery of Puerto Rico and the Virgin Islands concerning red hind spawning aggregation closure, including a regulatory impact review and an environmental assessment. Caribbean Fishery Management Council, San Juan, P.R. 35 pp.

Ditty, J.G., and R.F. Shaw. 1994. Preliminary guide to the identification of the early life history stages of sciaenid fishes from the Western Central Atlantic. NOAA Tech. Memorandum. NMFS-SEFSC-349. 118 pp.

Doherty, P.J. 1981. Coral reef fishes: Recruitment-limited assemblages? Proc. Int. Coral Reef Symp. 4th 2: 465-470.

Doherty, P.J. 1983. Tropical territorial damselfishes: Is density limited by aggression or recruitment? Ecology 64: 176-190.

Doherty, P.J., D. McB. Williams, and P.F. Sale.1985. The adaptive significance of larval dispersal in coral reef fishes. Environ. Biol. of Fish 12 (92): 81-90.

Doherty, P.J. 1991. Spatial and temporal patterns in recruitment. Pages 261-292 in P.F. Sale ed. The Ecology of Fishes on Coral Reefs. Academic Press, Inc. New York.

Duray, M.N., C.B. Estudillo, and L.G. Alpasan. 1997. Larval rearing of grouper *Epinephelus suillus* under laboratory conditions. Aquaculture 150: 63-76.

Emery, A.R. 1972. Eddy formation from a oceanic island: ecological effects. Carib. Journ. of Sci. 12: 121-128.

Eschmeyer, W.N. 1990. Catalog of the genera of Recent Fishes. San Francisco: Calif. Acad. Sci. 697 p.

Farooqi, T., R.F. Shaw, and J.G. Ditty. 1995. Preliminary guide to the identification of the early life history stages of anchovies (Family Engraulidae) of the Western Central Atlantic. NOAA Technical memorandum NMFS-SEFSC-358.

Frank, K.T. and McRuer, J. K. 1989. Nutritional status of field-collected haddock (*Melanogrammus aeglefinus*) larvae from southwestern Nova Scotia: An assessment based on morphometric and vertical distribution data. Can. J. Fish. Aquat .Sci. 46. 125-133.

García, J., Ojeda, E., González, A. 1995. Zooplankton/Ichthyoplankton communities of Guayanilla and Tallaboa Bays: Taxonomic structure and spatial/temporal abundance patterns. Dep. of Mar. Sci., Univ. of P.R.

García-Moliner, G.E. 1986. Aspects of the social spacing, reproduction and sex reversal in the red hind E. guttatus M.Sc. thesis, University of Puerto Rico, Mayagüez, P.R.

Giese, G. S., D. C. Chapman, P. G. Black and J. A. Fornshell.1990. Causation of large-amplitude coastal seiches on the Caribbean coast of Puerto Rico, Journal of Physical Oceanography, 20: 1449 - 1458.]

González, A.J. 2002. Vertical and temporal distribution patterns and taxonomic composition of ichthyoplankton and zooplankton off the insular shelf-edge at Guayanilla Bay, southwest Puerto Rico. Master of Sci. thesis, Dept. of Mar. Sci. Univ. of P.R.

Gordon, A.L. 1967. Circulation of the Caribbean Sea. Journ. Geophysical Research. 72 (24): 6207-6223.

Gray, C. A.. 1993. Horizontal and vertical trends in the distributions of larval fishes in coastal waters off central New South Wales, Australia. Mar. Biol. 116: 649-666.

Hempel, G. 1979. Early Life History of Marine Fish, the egg stage. Div. of Mar. Res. / University of Washington. Washington Sea Grant Pub. QL639.25.H45.

Henri, M., Dodson, J. J. and Powles, H. (1985) Spatial configurations of young herring (*Clupea harengus harengus*) larvae in the St. Lawrence estuary: importance of biological and physical factors. Can. J. Fish. Aquat., Sci., 42, 91-104.

Hensley, D.A., R.S. Appeldoorn, D.Y. Shapiro, M.Ray and R.G. Turingan. 1994. Egg dispersal in a Caribbean coral reef fish, *Thalassoma bifasciatum*, I- Dispersal over the reef platform, Bull. Mar. Sci.

Houde, E.D. and A.K. Taniguchi. 1977. Procedures used to culture larvae of marine fishes at the Rosentiel School of Marine and Atmospheric Sciences. Rep. To U.S. Environmental Protection Agency. 17pp.

Humphries, P., A.J. King and J.D. Koehn. 1999. Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia. Env. Biol. of fishes 56: 129-151. In: When do fishes become juveniles? G.H. Coop, V. Kovac and K. Hensei (eds.), Dordrecht, The Netherlands.

Hunter, J.R. 1981. Feeding ecology and predation of marine fish larvae. In: Marine Fish Larvae (Morphology, Ecology and Relation to Fisheries). Washington Sea Grant Program, Univ. of Washington. 34-77.

Jahn A.E. and R.J. Lavenberg. 1986 . Fine scale distribution of nearshore suprabentic fish larvae. Mar. Ecol. Prog. Ser. 31: 223-231.

Johannes, R.E. 1978 Reproductive strategies of coastal marine fishes in the tropics. Envir. Biol. Fish. 3: 65-84.

Jones, P.W., F.D. Martin and J.D. Hardy. 1978. Development of fishes of the Mid-Atlantic Bight. U.S. Fish and Wildlife Service. U.S. Department of the Interior. Library of Congress Card 1-6: 7786193.

Jones, P.W., M.J. Milicich, M.J. Emslie and C. Lunow. 1999. Self-recruitment in a coral reef population. Nature 402: 802-804.

Jones, D.L., 1993. Description of egg and early larval stages of two laboratory-reared tropical reef labrids, *Bodianus rufus* (Linnaeus, 1758) and *Thalassoma bifasciatum* (Bloch, 1791). Master of Science Thesis, Department of Marine Sciences, University of Puerto Rico.

Kendall, A. W. 1979. Morphological comparisons of North American Sea Bass larvae (Pisces: Serranidae). NOAA Technical report NMFS Circular 428.

Kingsford, M.J., J.M. Leis, A. Shanks, K.C. Lindeman, S.G. Morgan and J. Pineda. 2002. Sensory environments, larval abilities and local self-recruitment. Bull. Mar. Sci. 70(1): 309-340.

Kuo, C.M. 1995. The groupers. In Production of aquatic animals: fishes. Elsevier Science, Amsterdam. 305-318.

Lasker, R. 1975. Field criteria for survival of anchovy larvae: the relation between inshore chlorophyll maximum layers and successful first feeding. U.S. Fish. Bull. 73:453-462.

Lasker, R. 1981. Marine Fish Larvae. Morphology, Ecology, and Relation to Fisheries. Washington Sea Grant. Univ. of Wash.

Lee, T.N., M. E. Clarke, E. Williams, A. F. Szmant and T. Burger. 1994. Evolution of the Tortugas gyre and its influence on recruitment in the Florida Keys. Bull. Mar. Sci. 54(3): 621-646.

Lee, T.N., and E.Williams. 1999. Mean distribution and seasonal variability of coastal currents and temperature in Florida Keys with implications for larval recruitment. Bull. Mar. Sci. 64(1): 35-56.

Lee, T.N., C. Rooth, E. Williams, N.McGowan, A.F. Szmant and M. E. Clarke. 1992. Influence of Florida current, gyres and wind-driven circulation of transport of larvae and recruitment in the Florida local reefs. Continental Shelf Research. 12 (7/8): 971-1002.

Leis, J. M. 1982. Nearshore distributional gradients of larval fish (15) taxa and planktonic crustaceans (6) taxa in Hawaii. Mar. Biol. 72: 89-97.

Leis, J.M. 1984. Review of the early life history of tropical Groupers (Serranidae) and Snapers (Lutjanidae). In Tropical Snappers and Groupers: Biology and Fisheries Management. J.J. Polowina and S. Ralston (eds). 4: 189-237.

Leis, J. M. 1986. Vertical and horizontal distribution of fish larvae near coral reefs at Lizard Island, Great Barrier Reef, Mar. Biol. 90: 505-516.

Leis, J. M. 1991. The pelagic stage of reef fishes: the larval biology of coral reef fishes. In P.F. Sale, ed. The Ecology of Fishes on Coral Reefs. Academic Press, Inc. NewYork. Pp 183-229

Leis, J. M. 1994. Coral Sea atoll lagoons: closed nurseries for the larvae of a few coral reef fishes. Bull. Mar. Sci. 54 (1): 206-227.

Leis, J. M. and J.M. Miller. 1976. Offshore Distributional Patterns of Hawaiian Larvae. Mar. Biol. 36: 359-367.

Leis, J. M. and D.S. Rennis. 1983. The larvae of Indo-Pacific Coral Reef Fishes. Univ. of Hawaii Press. Honolulu, Hawaii. 269 pp.

Leis, J. M. and T. Trnski. 1989. The larvae of Indo Pacific Shore Fishes. Univ. of Hawaii Press. Honolulu Hawaii. 371 pp.

Leis, J.M. and Stobutzki, I.C. 1999. Swimming performance of late pelagic larvae of coral-reef fishes.: In situ and Laboratory-based measurements. Proc. 5th Indo-Pac. Fish. Conf. 1, 575-583.

Leis, J.M., B.M. Carson-Ewart and D.H. Cato. 2002. Sound detection *in situ* by the larvae of a coral reef fish damselfish (Pomacentridae). Mar. Ecol Prog. Ser. 232: 259-268.

Limouzi-Paris, C.B., H.C. Graber, D.L. Jones, A.W. Röpke and W.J. Richards. 1997. Translocation of larval coral reef fishes via sub-mesoscale spin-off eddies from the Florida current. Bull. Mar. Sci. 60(3): 966-983.

Lindeman, K.C. 1986. Development of larvae of the French grunt. *Haemulon flavolineatum*., and comparative development of twelve species of Western Atlantic *Haemulon* (PERCOIDE, HAEMULIDAE). Bull. Mar. Sci. 39(3): 673-716.

Lobel, P.S. 1978. Diel, lunar and seasonal periodicity in the reproductive behavior of the pomacanthid fish, *Centropyge potteri* and some other reef fishes in Hawaii. Pacific Science 32 (2): 193-207.

Lobel, P.S. and A.R. Robinson. 1988. Larval fishes and zooplancton in a cyclonic eddy in Hawaiian waters. Journal of Plankton Research 10 (6): 1209-1223.

Matarase, A.C., A.W. Kendall, Jr, D.M. Blood and B.M. Vinter. 1989. Laboratory guide to early life history stages of Northeast Pacific fishes. NOAA. Technical Report 80.

May. R.C. 1971. Effects of delayed initial feeding on larvae of grunion, *Leuesthes tenuis* (Aures). U.S. Fish. Bull. 69: 411-425

McFarland, W.N., E.B. Brothers, J.C. Ogden, M.J. Shulman, E.L. Bermingham, and N.M. Kotchian-Prentiss. 1985. Young french gruts, *Haemulon flavolineatum* (Family Haemulidae), At St.Croix, Virgin Islands. Fish. Bull. 83 (3): 413-426.

Molinary, R.L., M. Spillane, I. Brooks, and D. Atwood. 1978. Surface Currents in the Caribbean Sea as deduced from lagrangian observations. NOAA-Atlantic oceanographic and meteorological laboratories, Florida.

Mora, C. and P.F. Sale. 2002. Are population of coral reef fish open or closed? Trends in Ecology & Evolution.17 (9): 472-478.

Moser, H.G., W. J. Richards, D.M. Cohen, M.P. Fahay, A.W. Kendall, and S.L. Richardson. 1984. Ontogeny and systematics of fishes. Special Publication No. 1. The Amer. Soc. of Ichthyologists and Herpetologists. Allen Press Inc., Lawrence. 760 pp.

Moser, H. G. 1996. The early stages of fishes in the California current region. CALCOFI Atlas No. 33, NMFS. Allen Press, Inc. Lawrence. 1505 pp.

Mullineaux, L.S. and S.C. France. 1995. Dispersal mechanisms of deep-sea hydrothermal vent fauna. Pages 408-424 in Seaflor hydrothermal systems: physical, chemical, biological, and geological interactions. Geophys. Monogr. 91.

Munro, J.L., V.C. Gaut, R. Thompson and P.H. Reeson. 1973. The spawning seasons of Caribbean reef fishes. J. Fish. Biol. (5): 69-84.

Nielson, J. D., Perry, R. I., Valerio, P. and Waiwood, K. G. (1986) Condition of Atlantic cod *Gadus morhua* larvae after the transition to exogenous feeding: morphometrics, buoyancy and predator avoidance. Mar. Ecol. Prog. Ser. (32): 229-235.

Page, F. H., Frank, K. T. and Thompson, K. R. (1989) Stage dependent vertical distribution of haddok (*Melanogrammus aeglefinus*) eggs in a stratifies water column: Observations and model. Can. J. Fish. Aquat. Sci., 46, 55 - 67.

Pineda, J. 1991. Predictable Upwelling and shoreward Transport of Planktonic Larvae by Internal Tidal Bores. Science 253: 548-551.

Powell, A.B. and J.W. Tucker. 1992. Egg and larval development of laboratory-reared Nassau grouper, *Epinephelus striatus* (Pisces, Serranidae) Bull. of Mar. Sci. 50(1): 171-185 p.

Quintero, H., E. Ojeda, A. Cabarcas, D.E. Alston and J.Capella. 2001. Preliminary spawning induction of the red hind grouper in Puerto Rico. Poster in Open Ocean Aquac. Symp., New Brunswick, Canada.

Ramírez, J. T. 2000. Crosshelf distribution patterns of ichthyoplankton in La Parguera Bay and adjacent oceanic waters, southwest coast of Puerto Rico. Ph.D. thesis, Dep. of Mar. Sci., Univ. of P.R.

Richards, W. J. 1984. Kinds and abundances of fish larvae in the Caribbean Sea and adjacent areas. NOAA Tech. Rep. NMFS 776.

Richards, W. J. 1989. Preliminary guide to the identification of the early life history stages of scombroid fishes of the Western Central Atlantic. NOAA. Technical memorandum NMFS-SEFC-240.

Richards, W. J. 1994. Guide for the identification of early life history (ELH) stages, from western central Atlantic Ocean. Revision of NOAA Tech. Mem. NMFS-SEFC-267.

Richards, W. J., K. C. Lindeman, J. L..-Shultz, J. M. Leis, A. Ropke, M. E. Clarke and B. H. Comyns. 1994. Preliminary guide to the identification of the early life history stages of Lutjanid fishes on the Central Atlantic. NOAA Tech. Mem. NMFS-SEFSC-345. 49 p.

Richards, W.J. 2000. Preliminary guide to the identification of the early history stages of Ichthyoplankton of the Western Central Atlantic. Southeast Fisheries Sci. Center., NOAA, Miami. <http://208.152.233.21//noaa/ichthyoplankto.htmn>

Riley, C.M., G.H. Holt and C.R. Arnold. 1995. Growth and morphology of larval and juvenile cative bred yellowtail snapper, Ocyurus chrysurus. Fishery Bulletin. 93: 179-185,

Roberts, C.M., W.J. Ballantine, C.D. Buxton, P. Dayton, L.B. Crowder, W. Milon, M.K. Orbach, D. Pauly, J. Trexler. 1995. Review of the use of marine fishery reserves in the U.S. Southeastern Atlantic. NOAA Tech. Mem. NMFS-SEFSC.

Roberts, C.M. 1997. Connectivity and Management of Caribbean Coral Reefs. Science 278: 1454-1457.

Rojas, J. 2002. Caracterización del ictioplancton a través del canal de La Mona, con énfasis en familias arrecifales. Master in Sci. Thesis, Dept. of Mar. Sci., Univ. of P.R.

Sadovy, Y., and M. Figuerola. 1992. The status of the red hind fishery in Puerto Rico and St. Thomas as determined by yield per recruit analysis. Proc. Gulf Carib. Fish. Inst. 42nd Annual meeting 27pp.

Sadovy, Y., M. Figuerola and A. Román. 1992. Age and Growth of red hind, *Epinephelus guttatus*, in Puerto Rico and St. Thomas. Fish. Bull. 90: 516-528.

Sadovy, Y., A.Rosario and A. Román. 1994. Reproduction in an aggregating grouper, the red hind, *Epinephelus guttatus*. Env. Biol. of Fishes 41: 269-286.

Sadovy, Y. 1994. Grouper stocks of the western central Atlantic: the need for management and management needs. Proc. Gulf Caribb. Fish. Inst. 43: 43-64.

Sanknop, E.M., B.Y. Sumida, and H.G. Moser, 1984. Early life history descriptions, pp. 23-24. In H.G. Moser, Richards, W.J. Richards, D.M. Cohen, M.P. Fahay, A.W. Kendall, jr, and S.L. Richardson (eds.). Ontogeny and Systematics of fishes. Amer. Soc. Ichthyol. and Herpetol. Spec. Publ. 1.

Sale, P.F. 1970. Distribution of larval *Acanthuridae* of Hawaii. Copeia. 4: 765-766.

Sale, P.F. 1980. The ecology of fishes on coral reefs. Oceangr. Mar. Biol. 18: 367-421.

Scalafani, M., Taggart, C. T., Thompson, K. R. (1993) Condition, buoyancy and the distribution of larval fish: implications for vertical migration and retention. J. Plankton Res., 15 (4): 413 - 435.

Shanks, A. L. 1983. Surface slicks associated with tidally forced internal waves may transport pelagic larvae of benthic invertebrates and fishes shoreward.13: 311-315.

Shapiro, D.Y. 1987. Reproduction in groupers. In Tropical Snappers and Groupers, Biology and Fisheries management. Western Press, Boulder. 295-327.

Shapiro, D.Y., Y. Sadovy and M.A. McGehee. 1993a. Periodicity of sex change and reproduction in the red hind, *Epinephelus guttatus*. A protogynous grouper. Bull. of Mar. Sci. 53(3): 1151- 1162.

Shapiro, D.Y., Y. Sadovy and M.A. McGehee. 1993b. Size, composition, and spatial structure of the annual spwning aggregation of the red hind, *Epinephelus guttatus* (Pisces: Serranidae) Copeia (2): 399-406.

Shapiro, D.Y., G.G. Moliner and Y. Sadovy. 1993c. Social system of an inshore stock of the red hind grouper, *Epinephelus guttatus* (Pisces: Serranidae) Env. Biol. of Fishes 41: 415-422.

Shapiro, D.Y., D.A. Hensley and R.S. Appeldoorn. 1988. Pelagic spawning and egg transport in coral reef fishes: a skeptical overview. Env. Biol. of Fishes 22 (1): 3-14

Shulman, M. J. and E. Bermingham. 1995. Early life histories, ocean currents, and the population genetics of Caribbean reef fishes. Evolution 49 (5): 897-910.

Smith, C.L., J.C. Tyler and L. Stillman. 1987. Inshore ichthyoplankton a distinctive assemblage? Bull. of Mar. Sci. 41 (2): 432-440.

Sponaugle, S. and R.K, Cowen. 1996. Nearshore patterns of coral reef fish larval supply to Barbados, West Indies. Mar. Ecol. Prog. Ser.133: 13-28.

Sponaugle, S., R.K. Cowen, A.Shanks, S.G. Morgan, J.M. Leis, J. Pineda, G.W. Boehlert, M.J. Kingsford, K.C. Lindeman, C. Grimes and J.L. Munro. 2002. Predicting self-recruitment in marine populations: Biophysical correlates and mechanisms. Bull. of Mar. Sci. 70(1): 341-375.

Stobutzki, I.C. and Bellwood, D.R. 2002. The influence of swimming speed on sustained swimming performance of late-stage reef fish larvae. Mar. Biol. 140: 801-807.

Stobutzki, I.C. and D. R. Bellwood. 1994. An analysis of the sustained swimming abilities of pre- and post-settlement coral reef fishes. J. Exp. Mar. Biol. Ecol. 175: 275-286.

Stobutzki, I.C. and D. R. Bellwood. 1997. Sustained swimming abilities of the late pelagic stages of coral reef fishes. Mar. Ecol. Prog. Ser. 149: 35-41.

Swearer, S.E., J.E. Caselle, D.W. Lea and R.R. Warner. 1999. Larval retention and recruitment in an island population of a coral-reef fish. Nature 402: 799-802.

Swearer, S.E., J.S. Shima, M.E. Hellberg, S.R. Thorrold, G.P. Jones, D.R. Robertson, S.G. Morgan, K.A. Selkoe, G.M. Ruiz and R.R. Warner. 2002. Evidence of self-recruitment in demersal marine populations. Bull. Mar. Sci. 70(1): 251-271.

Thompson, R., J.L. Munro. 1978. Aspects of the biology and ecology of Caribbean reef fishes: Serranidae. J. Fish. Biol. 12: 115-146.

Tolimieri, N., A. Jeffs and J.C. Montgomery. 2000. Ambient sound as a cue for navigation by the pelagic larvae of reef fishes. Mar. Ecol. Ser. 207: 219-224.

Thresher, R. E., P. L. Colin and L. J. Bell. 1989. Planktonic duration, distribution, and population structure of western and central Pacific damselfishes (Pomacentridae). Copeia. 420-434.

Tucker, J. W. 1991. Induced Spawning of Nassau Grouper *Epinephelus striatus*. Jour. of the World Aqua. Soc. 22(3): 187-191.

Tucker, J.W. and D.E. Jory. 1991. Marine fish-culture in the Caribbean Region. World Aquaculture 22(1): 10-24.

Tucker, J. W., P. G. Bush, and S. T. Slaybaugh. 1993. Reproductive patterns of Cayman Islands Nassau Grouper (*Epinephelus striatus*) Populations. Bull. of Mar. Sci. 52 (3): 961-969.

Tucker, J. W. 1994. Spawning by Captive Serranid Fishes: A Review. Journ. of the World Aqua. Soc. 25 (3): 345-359.

Tucker, J.W. and P.N. Woodward. 1996. Nassau grouper aquaculture. In: F. Arrenguin-Sanchez, J.L. Munro, M.C. Baglos, and D. Pauly. The Biology and Ecology ot Tropical Groupers and Snappers. ICLARM Conference Proceedings, Manila.

Tucker, J.W., P.N. Woodward, and D.G. Sennett. 1996. Voluntary spawning of captive Nassau groupers *Epinephelus striatus* in concrete raceway. J. World Aquac. Soc.

Victor, B. C. 1986. Duration of the planktonic larval stage of one hundred species of Pacific and Atlantic wrasses (family Labridae). Mar. Biol. 90: 317-326.

Victor, B.C. 1987. Growth, dispersal, and identification of planktonic labrid and pomacentrid reef-fish larvae in the Eastern Pacific Ocean. Mar. Biol. 95: 145-152.

Watanabe, W.O., S.C. Ellis, E.P. Ellis, and V. García Lopez. 1996. Evaluation of first-feeding regimens for larval Nassau grouper *Epinephelus striatus* and preliminary, pilot-scale culture through metamorphosis. J. World Aquac. Soc. 27(3): 323-331.

Warner, R.R, and R.K. Cowen. 2002. Local retention of production in marine populations: evidence, mechanisms, and consequences. Bull. Mar. Sci. 70(1): 245-249.

Williams, D. McB., and J. C. Andrews. 1984. Transport mechanisms and the potential movement of planktonic larvae in the central region of the Great Barrier Reef, Coral Reefs 3: 229-236.

Wolanski, E., P. Doherty and J. Carleton. 1996. Passive and active dispersal of coral reef fish larvae. Aust. Inst. of Mar. Sci. . PNB No. 3 Townsville MC Q 4810, Australia

Wüst, G. 1964. Stratification and circulation in the Antillean-Caribbean basins, Part 1, Spreading and mixing of the water types with an oceanographic atlas. Columbia Univ. Press, New York. 201pp.

Appendix I: Taxonomic composition and abundance of fish larvae from La Parguera, Puerto Rico during a Jan-24 to Apr-9 (1997). Mean, total and (%) of total abundance are organized taxa . and by sampling date

January 24 FAMILY	3M Abund.	4M Abund.	5M Abund.	6M Abund.	9M Abund.	12M Abund.	Mean Abund.	Total Abund.	% of Total Abund.
Preflexion									
Nemichthyidae				0.07	0.08	0.30	0.09	0.45	0.26
Clupeiformes	2.23						0.45	2.23	1.28
Clupeidae	0.26						0.05	0.26	0.15
Engraulidae	3.75		1.59				1.07	5.35	3.05
Gonostomatidae				0.07			0.01	0.07	0.04
Chauliodontidae					0.17		0.03	0.17	0.10
Myctophidae			0.23	2.73	7.84	5.28	3.22	16.09	9.19
Paralepididae				0.07	0.08	0.33	0.10	0.48	0.27
Ophidiidae				0.07			0.01	0.07	0.04
Callionymidae	2.38				0.11		0.50	2.49	1.42
Exocoetidae						0.12	0.02	0.12	0.07
Holocentridae						0.24	0.05	0.24	0.14
Aulostomidae				0.19			0.04	0.19	0.11
Dactylopteridae						0.09	0.02	0.09	0.05
Scorpaenidae					0.25		0.05	0.25	0.14
Serranidae	2.54		5.18	0.87	0.23	0.09	1.78	8.92	5.09
Priacanthidae				0.30			0.06	0.30	0.17
Carangidae	0.93			0.14	0.18		0.25	1.26	0.72
Coryphaenidae				0.09			0.02	0.09	0.05
Lutjanidae	0.22		0.46	0.15			0.17	0.83	0.48
Haemulidae	1.50				0.08		0.32	1.58	0.90
Sparidae	0.96						0.19	0.96	0.55
Sciaenidae			0.58		0.17		0.15	0.75	0.43
Mullidae						0.12	0.02	0.12	0.07
Chaetodontidae				0.18			0.04	0.18	0.10
Pomacanthidae				0.09			0.02	0.09	0.05
Pomacentridae	2.65						0.53	2.65	1.51
Mugilidae				0.13			0.03	0.13	0.08
Sphyraenidae			0.29		0.63	0.36	0.26	1.28	0.73
Labridae	2.10			0.40	0.58		0.62	3.09	1.76
Scaridae				1.05	1.97	0.18	0.64	3.20	1.83
Opistognathidae				0.27		0.12	0.08	0.39	0.22
Tripterygiidae	3.39		4.43	2.25	3.52	0.74	2.86	14.32	8.18
Blenniidae	0.85		2.03				0.58	2.88	1.65
Gobiidae	11.05		23.36	0.45	0.28	0.23	7.07	35.36	20.20
Microdesmidae	0.26						0.05	0.26	0.15
Acanthuridae				0.08	0.66	1.78	0.50	2.52	1.44
Scombridae				0.31	0.25	0.12	0.13	0.67	0.38
Nomeidae					0.11		0.02	0.11	0.06
Pleuronectiformes	0.22		0.58	0.28	0.22		0.26	1.29	0.74
Achiridae				0.07	0.25		0.06	0.32	0.18
Paralichthyidae	0.26						0.05	0.26	0.15
Balistidae	1.07						0.21	1.07	0.61
Monacanthidae	0.28						0.06	0.28	0.16
Tetraodontiformes	3.24		2.20	0.05	0.32	0.28	1.22	6.09	3.48
Tetraodontidae			0.23				0.05	0.23	0.13
Diodontidae				0.08			0.02	0.08	0.04
Unidentified	40.87		4.86	4.69	3.72	0.83	11.00	54.98	31.40
PreflexionTotal	81.04		46.03	15.12	21.68	11.20	35.02	175.08	100.00

Appendix I (Cont.)

January 24 FAMILY	3M Abund.	4M Abund.	5M Abund.	6M Abund.	9M Abund.	12M Abund.	Mean Abund.	Total Abund.	% of Total Abund.
Postflexion									
Clupeidae	0.26						0.05	0.26	1.05
Engraulidae	0.43		0.78				0.24	1.21	4.87
Gonostomatidae				0.24		0.32	0.11	0.56	2.25
Myctophidae				0.62	1.12	0.79	0.51	2.53	10.16
Paralepididae						0.12	0.02	0.12	0.48
Gobiesocidae				0.07			0.01	0.07	0.28
Callionymidae				0.07			0.01	0.07	0.27
Belonidae				0.05			0.01	0.05	0.20
Hemiramphidae			0.26				0.05	0.26	1.04
Exocoetidae						0.12	0.02	0.12	0.48
Syngnathidae	0.43						0.09	0.43	1.74
Serranidae			1.01	0.09	0.17		0.26	1.28	5.12
Apogonidae			0.29	0.10			0.08	0.39	1.57
Carangidae				0.18			0.04	0.18	0.72
Lutjanidae	0.22			0.07			0.06	0.28	1.13
Gerreidae						0.09	0.02	0.09	0.37
Haemulidae	0.22						0.04	0.22	0.87
Sparidae	0.83						0.17	0.83	3.34
Chaetodontidae				0.28			0.06	0.28	1.13
Pomacentridae			0.69	0.05	0.17	0.09	0.20	1.01	4.04
Sphyraenidae				0.09			0.02	0.09	0.38
Labridae				0.63	0.11	0.49	0.25	1.23	4.92
Scaridae	0.65			0.54		0.28	0.29	1.46	5.86
Tripterygiidae	1.22		6.43				1.53	7.65	30.66
Labrisomidae				0.05			0.01	0.05	0.20
Blenniidae				0.05			0.01	0.05	0.20
Gobiidae			1.65	0.75	0.17	0.09	0.53	2.67	10.69
Microdesmidae			0.49				0.10	0.49	1.97
Acanthuridae					0.11		0.02	0.11	0.43
Siganidae						0.09	0.02	0.09	0.37
Scombridae				0.08		0.09	0.03	0.17	0.67
Achiridae				0.12			0.02	0.12	0.50
Monacanthidae					0.11	0.09	0.04	0.20	0.80
Diodontidae				0.08		0.23	0.06	0.31	1.23
Postflexion Total	4.26		11.61	4.22	1.95	2.89	4.99	24.94	100.00
Total	85.30		57.64	19.34	23.63	14.10	40.00		

Appendix I (Cont.)

January 31 FAMILY	3M Abund.	4M Abund.	5M Abund.	6M Abund.	9M Abund.	12M Abund.	Mean Abund.	Total Abund.	% of Total Abund.
Preflexion									
Clupeiformes	1.97	0.20					0.36	2.17	0.59
Clupeidae	5.04	0.75		0.12			0.99	5.91	1.60
Engraulidae	0.54	5.49					1.01	6.03	1.64
Gonostomatidae		0.18	0.19	1.12	0.39	0.86	0.46	2.74	0.74
Phosichthyidae				0.18		0.14	0.05	0.32	0.09
Neoscopelidae					0.12		0.02	0.12	0.03
Myctophidae	12.28	2.19	13.51	8.06	20.19	40.96	16.20	97.18	26.35
Paralepididae				0.10			0.02	0.10	0.03
Ophidiidae				0.05	0.14		0.03	0.19	0.05
Bythitidae		0.59	0.96				0.26	1.54	0.42
Lophiformes				0.05			0.01	0.05	0.01
Ogcocephalidae				0.05			0.01	0.05	0.01
Gobiesocidae	0.18	1.38	0.58				0.36	2.14	0.58
Belonidae					0.12		0.02	0.12	0.03
Trachipteridae						0.15	0.02	0.15	0.04
Syngnathidae		0.18					0.03	0.18	0.05
Dactylopteridae				0.05	0.50	0.15	0.11	0.69	0.19
Scorpaenidae				0.06			0.01	0.06	0.02
Serranidae	0.17	2.48		0.13			0.46	2.78	0.75
Echeneidae					0.27	0.14	0.07	0.40	0.11
Carangidae	0.53		0.37				0.15	0.90	0.24
Coryphaenidae			0.41			0.57	0.16	0.98	0.27
Bramidae				0.18			0.03	0.18	0.05
Lutjanidae		3.19		0.17			0.56	3.36	0.91
Haemulidae		2.73	0.21				0.49	2.94	0.80
Sciaenidae	0.69			0.29			0.16	0.98	0.27
Mullidae		0.20		0.05			0.04	0.25	0.07
Pomacentridae	7.64	7.57	7.60				3.80	22.81	6.19
Sphyraenidae		0.40		0.63	0.25	0.14	0.24	1.42	0.38
Labridae	0.31	0.38	0.21	0.16			0.18	1.05	0.29
Scaridae		0.40		0.30			0.12	0.70	0.19
Opistognathidae				0.05			0.01	0.05	0.01
Tripterygiidae	4.20	34.40	10.41	0.81			8.30	49.82	13.51
Blenniidae	0.97	0.64	0.97	0.04			0.44	2.62	0.71
Gobiidae	9.96	24.13	5.56	0.16		0.14	6.66	39.94	10.83
Microdesmidae	0.90				0.28		0.20	1.19	0.32
Gempylidae				0.05	0.76	0.43	0.21	1.25	0.34
Scombridae	0.35		0.37	0.56	3.28	8.02	2.10	12.57	3.41
Nomeidae		0.18	1.74	0.49	1.28		0.62	3.69	1.00
Pleuronectiformes	0.80	0.76					0.26	1.56	0.42
Achiridae				0.04			0.01	0.04	0.01
Tetraodontiformes	3.52	3.55	2.13				1.54	9.21	2.50
Diodontidae	0.13				0.25		0.06	0.37	0.10
Unidentified	27.46	41.49	10.35	3.84	3.39	1.40	14.66	87.94	23.85
PreflexionTotal	77.64	133.48	55.57	17.77	31.23	53.09	61.46	368.78	100.00

Appendix I (Cont.)

January 31	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**
Postflexion									
Clupeidae				0.08			0.01	0.08	0.25
Engraulidae	0.46	0.18					0.11	0.64	1.89
Gonostomatidae		0.18	0.19	0.71	1.51	1.28	0.65	3.87	11.46
Phosichthyidae				0.16	0.12		0.05	0.28	0.84
Neoscopelidae				0.05			0.01	0.05	0.15
Myctophidae	0.17		1.16	1.12	2.26	1.70	1.07	6.41	18.97
Paralepididae				0.09			0.02	0.09	0.28
Ophidiidae				0.05			0.01	0.05	0.15
Bythitidae		0.79	1.35				0.36	2.14	6.33
Gobiesocidae		0.20		0.10			0.05	0.30	0.90
Callionymidae				0.26			0.04	0.26	0.77
Belonidae					0.12		0.02	0.12	0.37
Hemiramphidae	0.13			0.10	0.50		0.12	0.72	2.13
Exocoetidae				0.05			0.01	0.05	0.16
Syngnathidae	1.40	2.63					0.67	4.03	11.92
Dactylopteridae					0.12		0.02	0.12	0.37
Scorpaenidae				0.10			0.02	0.10	0.30
Serranidae				0.05			0.01	0.05	0.16
Grammistidae				0.04			0.01	0.04	0.11
Coryphaenidae					0.12		0.02	0.12	0.37
Bramidae				0.09			0.02	0.09	0.28
Lutjanidae		0.20		0.04			0.04	0.24	0.70
Haemulidae		0.98	0.21				0.20	1.19	3.52
Sphyraenidae				0.05			0.01	0.05	0.16
Labridae				0.38		0.28	0.11	0.66	1.95
Scaridae				0.71			0.12	0.71	2.11
Tripterygiidae	0.13	3.46	4.56				1.36	8.14	24.10
Blenniidae		0.18	0.19				0.06	0.37	1.09
Gobiidae		0.18	0.19	0.77			0.19	1.14	3.37
Acanthuridae					0.14	0.14	0.05	0.28	0.84
Gempylidae					0.37	0.28	0.11	0.66	1.95
Scombridae				0.05	0.12	0.43	0.10	0.60	1.79
Nomeidae				0.05			0.01	0.05	0.13
Bothidae				0.05			0.01	0.05	0.15
Postflexion Total	2.27	8.98	7.84	5.16	5.41	4.12	5.63	33.79	100.00
Total	79.91	142.46	63.41	22.93	36.64	57.21	67.09		

Appendix I (Cont.)

February 7	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.
Preflexion									
Nemichthyidae				0.10			0.02	0.10	0.05
Clupeiformes			0.59				0.10	0.59	0.28
Clupeidae		0.15		0.05			0.03	0.21	0.10
Engraulidae	19.70	0.69	0.91	0.18		0.14	3.60	21.62	10.11
Gonostomatidae				0.22	0.36	0.13	0.12	0.71	0.33
Phosichthyidae				0.16	0.24	0.13	0.09	0.53	0.25
Neoscopelidae		0.15					0.03	0.15	0.07
Myctophidae		2.43	2.05	5.76	8.01	4.93	3.86	23.18	10.84
Paralepididae				0.11		0.22	0.06	0.34	0.16
Evermannellidae					0.24		0.04	0.24	0.11
Bregmacerotidae				0.05			0.01	0.05	0.02
Batrachoididae				0.05			0.01	0.05	0.02
Bythitidae			1.86				0.31	1.86	0.87
Lophiformes			0.37				0.06	0.37	0.17
Gobiesocidae		0.30	0.23				0.09	0.53	0.25
Hemiramphidae						0.13	0.02	0.13	0.06
Holocentridae						0.28	0.05	0.28	0.13
Syngnathidae		0.16					0.03	0.16	0.07
Dactylopteridae					0.12	0.13	0.04	0.25	0.12
Scorpaenidae			0.18				0.03	0.18	0.09
Serranidae	2.99	0.14	0.30	0.42		1.06	0.82	4.91	2.30
Carangidae		0.14	0.37	0.38		0.22	0.19	1.11	0.52
Coryphaenidae				0.23		0.37	0.10	0.60	0.28
Lutjanidae				0.06			0.01	0.06	0.03
Gerreidae		0.07					0.01	0.07	0.03
Haemulidae	3.03		0.38			0.13	0.59	3.54	1.65
Sciaenidae	0.39			0.06			0.08	0.46	0.21
Mullidae		0.31		0.06			0.06	0.38	0.18
Kyphosidae				0.12			0.02	0.12	0.05
Pomacanthidae				0.05			0.01	0.05	0.02
Pomacentridae	12.38	3.53	18.85	0.51		0.13	5.90	35.41	16.56
Mugilidae				0.05			0.01	0.05	0.02
Sphyraenidae		0.82	0.23	0.11	0.12	0.26	0.26	1.54	0.72
Labridae	1.45	0.47	0.18	0.24	0.12	0.28	0.46	2.75	1.29
Scaridae					0.31		0.05	0.31	0.14
Opistognathidae			0.37				0.06	0.37	0.17
Tripterygiidae	3.60	13.06	11.35				4.67	28.01	13.10
Blenniidae	0.39	0.29	0.15				0.14	0.83	0.39
Gobiidae	2.96	0.38	2.06	0.34		1.57	1.22	7.31	3.42
Microdesmidae	0.82	0.23	0.18				0.20	1.23	0.57
Acanthuridae				0.15	0.12		0.05	0.28	0.13
Gempylidae				0.06	0.10		0.03	0.17	0.08
Scombridae		1.78	0.23	2.31	0.46	0.36	0.86	5.14	2.40
Nomeidae				0.79	0.38	1.24	0.40	2.41	1.13
Pleuronectiformes	0.71	0.07	0.23				0.17	1.01	0.47
Achiridae			0.15				0.02	0.15	0.07
Paralichthyidae				0.05			0.01	0.05	0.02
Tetraodontiformes	1.51	1.93	1.36	0.21			0.84	5.02	2.34
Tetraodontidae					0.24		0.04	0.24	0.11
Unidentified	29.81	6.13	19.20	1.13	0.72	1.83	9.80	58.81	27.50
PreflexionTotal	79.76	33.25	61.75	14.03	11.55	13.53	35.65	213.88	100.00

Appendix I (Cont.)

February 7 FAMILY	3M Abund.	4M Abund.	5M Abund.	6M Abund.	9M Abund.	12M Abund.	Mean Abund.	Total Abund.	% of Total Abund.
Postflexion									
Muraenidae					0.27	0.14	0.07	0.41	1.44
Clupeidae		0.15					0.03	0.15	0.54
Engraulidae	0.20						0.03	0.20	0.69
Gonostomatidae				0.28	0.31	0.14	0.12	0.72	2.52
Phosichthyidae				0.06			0.01	0.06	0.22
Melanostomiidae				0.05			0.01	0.05	0.17
Myctophidae	0.25	1.50	0.48	1.85	1.15	4.69	1.66	9.93	34.75
Ophidiidae				0.11			0.02	0.11	0.40
Bythitidae		0.22	0.71				0.15	0.92	3.23
Gobiesocidae		0.14					0.02	0.14	0.50
Callionymidae				0.16			0.03	0.16	0.55
Belonidae			0.15				0.02	0.15	0.52
Hemiramphidae					0.10		0.02	0.10	0.37
Syngnathidae	1.44	0.07	0.23	0.06			0.30	1.81	6.32
Serranidae				0.06	0.26	0.27	0.10	0.59	2.06
Apogonidae			0.56			0.13	0.11	0.69	2.41
Carangidae				0.12			0.02	0.12	0.41
Coryphaenidae		0.15				0.13	0.05	0.28	0.99
Bramidae						0.14	0.02	0.14	0.48
Lutjanidae			0.15				0.02	0.15	0.52
Gerreidae		0.31					0.05	0.31	1.09
Sparidae			0.18				0.03	0.18	0.64
Mugilidae				0.06			0.01	0.06	0.22
Sphyraenidae		0.15		0.06			0.04	0.21	0.74
Labridae			0.15	0.12	0.52		0.13	0.79	2.75
Scaridae				0.37	0.73	0.88	0.33	1.97	6.89
Opistognathidae			0.59				0.10	0.59	2.07
Tripterygiidae		0.31	2.60				0.49	2.91	10.20
Labrisomidae			0.44				0.07	0.44	1.55
Eleotridae				0.06	0.24	0.14	0.07	0.44	1.55
Gobiidae		0.07	0.52	0.60		0.69	0.31	1.89	6.60
Microdesmidae			0.15				0.02	0.15	0.52
Acanthuridae						0.55	0.09	0.55	1.93
Gempylidae						0.09	0.02	0.09	0.33
Scombridae				0.12			0.02	0.12	0.43
Nomeidae				0.14	0.12	0.23	0.08	0.50	1.73
Bothidae					0.26	0.22	0.08	0.48	1.68
Postflexion Total	1.89	3.09	6.92	4.29	3.96	8.43	4.76	28.58	100.00
Total	81.65	36.35	68.67	18.32	15.51	21.96	40.41		

Appendix I (Cont.)

February 19	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**
Preflexion									
Clupeiformes		5.29	10.45	0.62			2.73	16.36	5.76
Clupeidae	0.21		0.28	0.51			0.17	1.01	0.36
Engraulidae	15.50	11.74	0.56	0.14			4.66	27.94	9.84
Gonostomatidae		0.63		0.46	1.51	0.43	0.51	3.04	1.07
Melanostomiidae						0.29	0.05	0.29	0.10
Notosudidae					0.27		0.04	0.27	0.09
Myctophidae			2.53	3.04	2.08	10.60	3.04	18.26	6.43
Paralepididae					0.67	0.37	0.17	1.04	0.37
Gobiesocidae	0.45	0.20					0.11	0.65	0.23
Callionymidae	7.35	0.61		0.47			1.40	8.42	2.97
Hemiramphidae		0.55					0.09	0.55	0.19
Holocentridae				0.14		0.27	0.07	0.41	0.14
Scorpaenidae					0.14	0.15	0.05	0.29	0.10
Serranidae		0.35		0.61		0.15	0.18	1.11	0.39
Carangidae				0.18		0.12	0.05	0.30	0.11
Lutjanidae				0.18			0.03	0.18	0.06
Gerreidae		3.18	0.28		0.13		0.60	3.59	1.27
Sciaenidae	0.68		0.32	0.18			0.20	1.18	0.42
Mullidae		0.39	0.32				0.12	0.70	0.25
Chaetodontidae					0.14	0.25	0.07	0.39	0.14
Pomacanthidae				0.18			0.03	0.18	0.06
Pomacentridae	0.21	1.82	8.19	3.67			2.32	13.89	4.90
Mugilidae	4.79	0.79					0.93	5.57	1.96
Sphyraenidae	0.45	0.20		0.98		0.86	0.41	2.49	0.88
Labridae	0.45			0.51	0.70	0.58	0.37	2.24	0.79
Scaridae				0.15	0.56	0.15	0.14	0.86	0.30
Tripterygiidae	12.92	17.65	12.30	9.50			8.73	52.36	18.45
Blenniidae	0.21	0.20					0.07	0.41	0.14
Gobiidae	20.91	9.27	2.29	6.97		0.29	6.62	39.74	14.00
Microdesmidae	2.20	0.62					0.47	2.82	0.99
Acanthuridae					0.14	3.09	0.54	3.24	1.14
Gempylidae						0.12	0.02	0.12	0.04
Scombridae				0.18			0.03	0.18	0.06
Nomeidae					0.42		0.07	0.42	0.15
Pleuronectiformes	2.97	0.21	0.28				0.58	3.46	1.22
Bothidae					0.14		0.02	0.14	0.05
Tetraodontiformes	0.66	0.37	0.92	0.18			0.36	2.13	0.75
Tetraodontidae		0.42		0.14			0.09	0.56	0.20
Unidentified	11.75	13.49	17.55	19.75	2.86	1.62	11.17	67.02	23.61
PreflexionTotal	81.71	67.97	56.28	48.74	9.78	19.34	47.30	283.82	100.00

Appendix I (Cont.)

February 19	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.
Postflexion									
Engraulidae	0.70	0.39					0.18	1.10	4.88
Gonostomatidae				0.27	0.14	0.29	0.12	0.71	3.16
Phosichthyidae						0.15	0.02	0.15	0.66
Astronesthidae						0.13	0.02	0.13	0.59
Melanostomiidae						0.12	0.02	0.12	0.55
Myctophidae			0.63	0.18	2.09	1.19	0.68	4.10	18.19
Gobiesocidae				0.14			0.02	0.14	0.60
Callionymidae	1.52			0.14	0.13		0.30	1.79	7.94
Syngnathidae		0.39			0.13		0.09	0.53	2.35
Serranidae				0.29		0.13	0.07	0.42	1.88
Apogonidae					0.13		0.02	0.13	0.60
Carangidae					0.27	0.15	0.07	0.42	1.85
Bramidae					0.14		0.02	0.14	0.64
Gerreidae		0.90		0.41			0.22	1.31	5.82
Sciaenidae			0.63				0.11	0.63	2.81
Mullidae		0.21	1.23				0.24	1.44	6.41
Pomacanthidae		0.00			0.14		0.02	0.14	0.64
Pomacentridae					0.14		0.02	0.14	0.64
Sphyraenidae			0.28			0.15	0.07	0.43	1.91
Labridae			0.32			0.81	0.19	1.13	5.00
Scaridae				0.62		0.15	0.13	0.77	3.43
Tripterygiidae			1.45	0.56			0.33	2.01	8.92
Blenniidae	0.21			0.14			0.06	0.35	1.55
Gobiidae	0.21	0.62	0.60	1.61	0.55		0.60	3.59	15.95
Microdesmidae		0.41					0.07	0.41	1.81
Nomeidae					0.14	0.13	0.05	0.28	1.23
Postflexion Total	2.65	2.93	5.14	4.35	4.03	3.41	3.75	22.51	100.00
Total	84.36	70.90	61.42	53.09	13.81	22.75	51.06		

Appendix I (Cont.)

February 27	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**
Preflexion									
Nemichthyidae					0.21	0.10	0.05	0.31	0.09
Clupeidae	0.06	1.40		1.23			0.45	2.70	0.77
Engraulidae	6.12						1.02	6.12	1.76
Gonostomatidae					0.14	2.08	0.37	2.22	0.64
Phosichthyidae						0.10	0.02	0.10	0.03
Myctophidae	0.51	1.46	4.62	0.79	6.56	5.35	3.21	19.28	5.54
Paralepididae					1.00		0.17	1.00	0.29
Gobiesocidae			0.42				0.07	0.42	0.12
Callionymidae	4.38		0.10		0.43	0.18	0.85	5.09	1.46
Hemiramphidae				0.40			0.07	0.40	0.11
Holocentridae			0.22			0.08	0.05	0.30	0.09
Scorpaenidae					0.14	0.10	0.04	0.24	0.07
Triglidae						0.08	0.01	0.08	0.02
Serranidae		8.83	0.63	0.42	0.29	0.39	1.76	10.56	3.03
Carangidae				0.20		0.44	0.11	0.64	0.18
Lutjanidae		0.31		0.64			0.16	0.96	0.27
Gerreidae		0.77	0.42				0.20	1.19	0.34
Haemulidae		0.77		0.79			0.26	1.56	0.45
Sparidae	0.45						0.08	0.45	0.13
Sciaenidae	5.86		0.42	1.38			1.28	7.67	2.20
Mullidae			4.32			0.52	0.81	4.84	1.39
Kyphosidae						0.08	0.01	0.08	0.02
Chaetodontidae						0.10	0.02	0.10	0.03
Pomacentridae	0.93	5.21	7.15	10.62		0.10	4.00	24.00	6.90
Mugilidae			0.42	0.40			0.14	0.82	0.23
Sphyraenidae		1.15	1.09	0.22	0.43	0.55	0.57	3.45	0.99
Labridae		0.26	0.22	1.48	0.72	0.76	0.57	3.43	0.99
Scaridae					3.88	0.88	0.79	4.75	1.37
Opistognathidae	0.06						0.01	0.06	0.02
Dactyloscopidae			4.07				0.68	4.07	1.17
Tripterygiidae	2.18	22.74	12.87	16.50			9.05	54.28	15.60
Labrisomidae			6.13	1.09			1.20	7.21	2.07
Blenniidae		4.10	0.42				0.75	4.52	1.30
Eleotridae				0.20		0.10	0.05	0.30	0.08
Gobiidae	4.89	2.42	1.50	29.07	0.14		6.34	38.02	10.92
Microdesmidae		3.67	0.97			0.08	0.79	4.72	1.36
Acanthuridae					0.50	0.18	0.11	0.68	0.20
Scombridae		0.31	0.33	0.82	0.29	0.76	0.42	2.50	0.72
Nomeidae		0.32	0.21		0.50		0.17	1.03	0.30
Pleuronectiformes	3.11	0.51	0.84				0.74	4.46	1.28
Bothidae				0.79			0.13	0.79	0.23
Tetraodontiformes		0.94		1.68			0.44	2.62	0.75
Tetraodontidae			0.22				0.04	0.22	0.06
Unidentified	2.60	41.31	32.36	39.83	2.36	1.31	19.96	119.78	34.42
PreflexionTotal	31.15	96.49	79.97	108.55	17.59	14.29	58.00	348.03	100.00

Appendix I (Cont.)

February 27 FAMILY	3M Abund.	4M Abund.	5M Abund.	6M Abund.	9M Abund.	12M Abund.	Mean Abund.	Total Abund.	% of Total Abund.
Postflexion									
Gonostomatidae					0.36		0.06	0.36	1.82
Synodontidae						0.08	0.01	0.08	0.41
Myctophidae			0.45		0.78	0.80	0.34	2.03	10.32
Gobiesocidae				0.22			0.04	0.22	1.13
Callionymidae	0.46			0.20			0.11	0.66	3.36
Belonidae			1.09				0.18	1.09	5.57
Hemiramphidae	0.40						0.07	0.40	2.02
Syngnathidae				0.40			0.07	0.40	2.01
Scorpaenidae					0.14		0.02	0.14	0.74
Serranidae			0.42	0.20	0.14	0.08	0.14	0.85	4.31
Apogonidae			0.22	0.62			0.14	0.84	4.28
Carangidae						0.08	0.01	0.08	0.41
Coryphaenidae						0.16	0.03	0.16	0.81
Lutjanidae					0.36		0.06	0.36	1.82
Gerreidae	0.46	1.65	0.65				0.46	2.76	14.07
Haemulidae		0.31				0.10	0.07	0.41	2.10
Sparidae	0.40						0.07	0.40	2.02
Pomacanthidae					0.14		0.02	0.14	0.74
Pomacentridae					0.14		0.02	0.14	0.74
Labridae					0.14	0.60	0.12	0.74	3.78
Scaridae					0.86		0.14	0.86	4.38
Dactyloscopidae			0.67				0.11	0.67	3.42
Tripterygiidae		0.96	0.22				0.20	1.18	6.00
Labrisomidae		0.63	1.74				0.39	2.37	12.06
Chaenopsidae		0.32					0.05	0.32	1.63
Eleotridae					0.36		0.06	0.36	1.82
Gobiidae			0.22	0.22			0.07	0.45	2.27
Acanthuridae					0.57		0.10	0.57	2.90
Gempylidae						0.18	0.03	0.18	0.91
Scombridae						0.08	0.01	0.08	0.40
Nomeidae						0.10	0.02	0.10	0.50
Bothidae						0.10	0.02	0.10	0.50
Tetraodontidae					0.14		0.02	0.14	0.74
Postflexion Total	1.72	3.87	5.69	1.85	4.16	2.35	3.27	19.64	100.00
Total	32.87	100.37	85.66	110.40	21.74	16.64	61.28		

Appendix I (Cont.)

March 6	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.
Preflexion									
Muraenidae					0.17		0.03	0.17	0.08
Ophichthidae					0.30		0.05	0.30	0.14
Clupeiformes	1.28	7.89	0.94				1.69	10.11	4.68
Clupeidae	0.59	0.20	0.91		0.18		0.31	1.87	0.87
Engraulidae	9.91	1.93	0.17	0.43	0.18		2.11	12.64	5.85
Gonostomatidae		0.20			0.64	2.35	0.53	3.19	1.48
Phosichthyidae				0.45			0.07	0.45	0.21
Synodontidae				0.15			0.02	0.15	0.07
Myctophidae	1.03	1.04	3.27	4.95	6.98	4.89	3.69	22.16	10.25
Paralepididae				0.15		0.32	0.08	0.46	0.22
Bregmacerotidae				0.30			0.05	0.30	0.14
Ophidiidae	0.18						0.03	0.18	0.08
Bythitidae					0.36		0.06	0.36	0.17
Callionymidae	2.12					0.24	0.39	2.36	1.09
Atherinidae	0.17	0.20				0.15	0.09	0.51	0.24
Hemiramphidae		0.22					0.04	0.22	0.10
Holocentridae				0.63			0.11	0.63	0.29
Fistularidae			0.17				0.03	0.17	0.08
Triglidae				0.15			0.02	0.15	0.07
Serranidae	0.36	1.16	0.38	0.65	1.37		0.65	3.92	1.81
Carangidae			0.17		2.16	0.64	0.49	2.96	1.37
Coryphaenidae		0.52		0.50	0.17		0.20	1.20	0.55
Lutjanidae		0.57	0.34	2.38	1.59	0.45	0.89	5.35	2.47
Gerreidae	0.36						0.06	0.36	0.17
Haemulidae	0.71	1.52		0.15	2.01		0.73	4.39	2.03
Sparidae	0.17		0.38				0.09	0.54	0.25
Sciaenidae	1.30	2.18	0.72	0.94			0.86	5.15	2.38
Mullidae		1.46	0.56	0.60			0.44	2.62	1.21
Chaetodontidae	0.17						0.03	0.17	0.08
Pomacentridae	3.44	2.11	2.21	0.44	2.09	0.32	1.77	10.61	4.91
Sphyraenidae		0.37	0.17		1.52	0.15	0.37	2.21	1.02
Labridae	0.50		0.38	3.84	0.89		0.93	5.60	2.59
Scaridae					0.17		0.03	0.17	0.08
Opistognathidae	0.59	0.57	0.38				0.26	1.54	0.71
Dactyloscopidae			0.36				0.06	0.36	0.17
Tripterygiidae	5.99	6.55	10.81	1.24	0.18		4.13	24.77	11.46
Chaenopsidae			1.54				0.26	1.54	0.71
Labrisomidae	0.26						0.04	0.26	0.12
Blenniidae		2.18	1.06				0.54	3.24	1.50
Eleotridae			0.17				0.03	0.17	0.08
Gobiidae	8.62	0.60	2.60	1.90	0.18		2.32	13.91	6.43
Microdesmidae	0.62	1.91	0.38	0.00			0.48	2.91	1.35
Acanthuridae	0.26			0.15	0.17		0.10	0.58	0.27
Gempylidae						0.15	0.03	0.15	0.07
Trichiuridae		0.17					0.03	0.17	0.08
Scombridae				0.92	1.17	1.49	0.60	3.59	1.66
Nomeidae			0.34	0.63	0.17	0.15	0.22	1.30	0.60
Pleuronectiformes		0.20	0.36		0.18	0.33	0.18	1.07	0.49
Bothidae						0.24	0.04	0.24	0.11
Monacanthidae			0.19				0.03	0.19	0.09
Ostracidae		0.22					0.04	0.22	0.10
Tetraodontiformes	0.26		0.55	0.30	0.48		0.26	1.58	0.73
Tetraodontidae		1.12	0.17				0.21	1.29	0.60
Molidae						0.17	0.03	0.17	0.08
Unidentified	9.93	7.90	9.72	10.69	16.05	0.95	9.21	55.25	25.56
PreflexionTotal	48.81	43.01	39.39	32.54	39.38	12.98	36.02	216.11	100.00

Appendix I (Cont.)

March 6 FAMILY	3M Abund.	4M Abund.	5M Abund.	6M Abund.	9M Abund.	12M Abund.	Mean Abund.	Total Abund.	% of Total Abund.
Postflexion									
Engraulidae	0.51	0.22	0.17	0.21			0.19	1.12	3.74
Gonostomatidae					0.17	0.55	0.12	0.72	2.42
Phosichthyidae				0.30	0.34		0.11	0.64	2.14
Stomiidae				0.15			0.02	0.15	0.50
Melanostomiidae					0.17		0.03	0.17	0.57
Myctophidae			0.17	1.16	1.54	1.74	0.77	4.61	15.43
Paralepididae					0.18		0.03	0.18	0.61
Bregmacerotidae				0.15			0.02	0.15	0.50
Ophidiidae		0.17					0.03	0.17	0.58
Bythitidae			0.72	0.14			0.14	0.86	2.89
Gobiesocidae			0.70				0.12	0.70	2.35
Callionymidae	0.26		0.36	0.29	0.48	0.40	0.30	1.79	5.98
Belonidae		0.20				0.00	0.03	0.20	0.66
Hemiramphidae			0.36				0.06	0.36	1.20
Exocoetidae			0.34				0.06	0.34	1.14
Syngnathidae	0.84	0.20	0.34	0.21			0.27	1.59	5.34
Scorpaenidae				0.29			0.05	0.29	0.98
Serranidae				0.14	0.17		0.05	0.32	1.06
Carangidae					0.17		0.03	0.17	0.57
Coryphaenidae						0.15	0.03	0.15	0.50
Lutjanidae						0.15	0.03	0.15	0.50
Gerreidae	0.18		0.17	0.29			0.11	0.64	2.15
Haemulidae		0.35	0.00		0.47		0.14	0.82	2.74
Sparidae	0.17	0.17	0.19	0.21			0.12	0.74	2.48
Sciaenidae				0.14			0.02	0.14	0.49
Mullidae			0.19				0.03	0.19	0.63
Pomacentridae			0.19	0.21			0.07	0.40	1.34
Mugilidae	0.26		0.19				0.07	0.44	1.49
Sphyraenidae				0.15	0.18		0.06	0.33	1.11
Labridae				0.14		0.17	0.05	0.31	1.04
Scaridae				0.30	0.83		0.19	1.13	3.78
Opistognathidae	0.35	0.17					0.09	0.52	1.75
Dactyloscopidae			0.34				0.06	0.34	1.14
Tripterygiidae	0.26	0.17	1.61	0.51			0.42	2.55	8.53
Labrisomidae					0.18		0.03	0.18	0.61
Eleotridae						0.24	0.04	0.24	0.79
Gobiidae	0.53	0.20	1.45	0.73	0.72		0.61	3.63	12.16
Microdesmidae		0.40		0.21			0.10	0.61	2.04
Acanthuridae				0.21			0.04	0.21	0.71
Gempylidae				0.00		0.15	0.03	0.15	0.50
Scombridae				0.14		0.24	0.06	0.38	1.28
Achiridae				0.30			0.05	0.30	1.00
Bothidae						0.15	0.03	0.15	0.50
Balistidae					0.17	0.15	0.05	0.32	1.08
Tetraodontidae					0.30		0.05	0.30	1.00
Postflexion Total	3.35	2.26	7.49	6.60	6.08	4.09	4.98	29.87	100.00
Total	52.16	45.27	46.88	39.14	45.46	17.07	41.00		

Appendix I (Cont.)

March 14	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.
Preflexion									
Clupeiformes		2.50	0.54				0.61	3.05	0.97
Clupeidae		0.77	0.61	0.12			0.30	1.50	0.47
Engraulidae	19.90	5.20	3.39		0.24		5.75	28.73	9.11
Gonostomatidae				0.51	0.99		0.30	1.50	0.48
Myctophidae				3.19	1.55		0.95	4.75	1.50
Ophidiidae					0.21		0.04	0.21	0.07
Bythitidae			0.18				0.04	0.18	0.06
Antennariidae				0.23	0.34		0.11	0.57	0.18
Gobiesocidae					0.11		0.02	0.11	0.03
Callionymidae	11.35	0.19					2.31	11.54	3.66
Atherinidae	0.20						0.04	0.20	0.06
Hemiramphidae		0.39					0.08	0.39	0.12
Holocentridae			0.40		1.85		0.45	2.25	0.71
Triglidae					0.11		0.02	0.11	0.03
Serranidae	1.55	0.39	0.57	0.69	0.45		0.73	3.65	1.16
Priacanthidae					0.11		0.02	0.11	0.03
Apogonidae	0.72				0.11		0.17	0.83	0.26
Carangidae	0.36	0.40		0.49	1.72		0.59	2.96	0.94
Coryphaenidae					0.21		0.04	0.21	0.07
Lutjanidae	0.20	8.79	2.14				2.23	11.14	3.53
Gerreidae					0.11		0.02	0.11	0.03
Haemulidae	1.93	3.51	1.04	0.12			1.32	6.59	2.09
Sparidae					0.13		0.03	0.13	0.04
Sciaenidae	2.08	0.58		0.12	0.13		0.58	2.90	0.92
Mullidae			0.56		0.21		0.16	0.78	0.25
Kyphosidae	0.36						0.07	0.36	0.11
Pomacentridae	4.01	14.88	6.42	0.12	0.21		5.13	25.63	8.12
Mugilidae					0.52		0.10	0.52	0.16
Sphyraenidae	0.18			0.95	1.26		0.48	2.39	0.76
Polynemidae	0.54						0.11	0.54	0.17
Labridae	0.98	0.77		1.32	2.29		1.07	5.36	1.70
Dactyloscopidae			0.18				0.04	0.18	0.06
Tripterygiidae	11.18	12.94	26.51	1.32	0.21		10.43	52.15	16.53
Chaenopsidae			0.61				0.12	0.61	0.19
Labrisomidae	0.20						0.04	0.20	0.06
Blenniidae	0.20	0.96			0.26		0.28	1.42	0.45
Gobiidae	28.91	4.82	5.18	0.23	0.51		7.93	39.65	12.56
Microdesmidae	2.80	2.12		0.41			1.07	5.34	1.69
Acanthuridae				0.53	0.11		0.13	0.64	0.20
Gempylidae					0.24		0.05	0.24	0.08
Scombridae				2.03	1.01		0.61	3.04	0.96
Nomeidae		0.40		0.12			0.10	0.51	0.16
Tetragonuridae			1.83	0.26	0.21		0.46	2.30	0.73
Pleuronectiformes	0.41	0.19	0.39	0.41	0.10		0.30	1.50	0.48
Monacanthidae	0.18						0.04	0.18	0.06
Ostracidae			0.36	0.12			0.10	0.48	0.15
Tetraodontiformes	0.41	1.94	1.41				0.75	3.76	1.19
Tetraodontidae				0.32	0.36		0.14	0.68	0.22
Molidae					0.11		0.02	0.11	0.03
Unidentified	32.23	31.08	12.59	2.43	4.95		16.66	83.28	26.39
PreflexionTotal	120.93	92.81	64.91	16.01	20.91		63.11	315.56	100.00

Appendix I (Cont.)

March 14 FAMILY	3M Abund.	4M Abund.	5M Abund.	6M Abund.	9M Abund.	12M Abund.	Mean Abund.	Total Abund.	% of Total Abund.
Postflexion									
Clupeidae		0.19					0.04	0.19	0.80
Engraulidae	1.21	1.17	0.62				0.60	3.00	12.47
Chauliodontidae				0.46			0.09	0.46	1.92
Melanostomiidae					0.10		0.02	0.10	0.43
Myctophidae				0.26	1.11		0.27	1.37	5.69
Paralepididae				0.21			0.04	0.21	0.86
Bythitidae		0.59	0.59				0.24	1.18	4.93
Gobiesocidae							0.00	0.00	0.00
Callionymidae			0.21	0.41			0.12	0.62	2.58
Hemiramphidae	0.18	0.58					0.15	0.76	3.16
Exocoetidae			0.18				0.04	0.18	0.75
Holocentridae	0.39		0.18				0.11	0.57	2.36
Syngnathidae	0.81	0.39	0.18				0.27	1.37	5.71
Scorpaenidae					0.11		0.02	0.11	0.46
Apogonidae	0.72	0.40					0.22	1.12	4.67
Carangidae					0.24		0.05	0.24	0.99
Coryphaenidae					0.21		0.04	0.21	0.86
Lutjanidae		0.40	0.18	0.37	0.10		0.21	1.05	4.38
Gerreidae	0.21	0.39		0.26	0.10		0.19	0.95	3.97
Haemulidae	0.36	0.39					0.15	0.75	3.11
Sparidae	0.20						0.04	0.20	0.85
Mugilidae					0.10		0.02	0.10	0.43
Polynemidae	0.57						0.11	0.57	2.36
Labridae					0.10		0.02	0.10	0.43
Scaridae				0.26			0.05	0.26	1.07
Dactyloscopidae			0.18				0.04	0.18	0.75
Tripterygiidae		1.18	3.57				0.95	4.74	19.75
Chaenopsidae			1.01				0.20	1.01	4.21
Eleotridae					0.11		0.02	0.11	0.46
Gobiidae	0.18	0.19	0.18	0.51	0.13		0.24	1.20	4.98
Microdesmidae	0.18	0.39					0.11	0.57	2.36
Gempylidae					0.11		0.02	0.11	0.46
Nomeidae					0.11		0.02	0.11	0.46
Tetragonuridae		0.19					0.04	0.19	0.80
Monacanthidae					0.13		0.03	0.13	0.53
Postflexion Total	5.01	6.42	7.08	2.73	2.77		4.80	24.01	100.00
Total	125.93	99.23	71.98	18.75	23.68		67.92		

Appendix I (Cont.)

March 21	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.
Preflexion									
Ophichthyidae				0.09	0.07		0.03	0.16	0.05
Clupeiformes	0.85						0.17	0.85	0.25
Clupeidae	0.51	3.53	0.27				0.86	4.31	1.29
Engraulidae	12.48	3.52	0.11				3.22	16.11	4.80
Gonostomatidae			0.13	0.50	0.62		0.25	1.25	0.37
Myctophidae			0.65	2.26	3.25		1.23	6.15	1.83
Paralepididae				0.50	0.19		0.14	0.69	0.20
Ophidiidae				0.07	0.18		0.05	0.25	0.07
Bythitidae			0.14				0.03	0.14	0.04
Gobiesocidae		0.29					0.06	0.29	0.09
Callionymidae	11.90		0.13				2.41	12.03	3.58
Atherinidae		0.15					0.03	0.15	0.04
Lampriformes				0.08			0.02	0.08	0.02
Holocentridae		0.15	0.26	0.15	0.07		0.13	0.63	0.19
Scorpaenidae				0.07			0.01	0.07	0.02
Serranidae	0.45		0.66	0.68	0.66		0.49	2.45	0.73
Echeneidae	0.34						0.07	0.34	0.10
Carangidae		0.60	1.24	0.88	0.26		0.59	2.97	0.89
Coryphaenidae			0.24	0.15	0.26		0.13	0.65	0.19
Lutjanidae	1.57	2.26	0.49	0.23			0.91	4.55	1.35
Gerreidae			2.32				0.46	2.32	0.69
Haemulidae	1.51	6.47					1.59	7.97	2.38
Sparidae	1.21	0.15	0.24				0.32	1.60	0.48
Sciaenidae	4.69	0.81			0.07		1.12	5.58	1.66
Mullidae		0.15	4.66				0.96	4.81	1.43
Chaetodontidae				0.15			0.03	0.15	0.04
Pomacanthidae					0.16		0.03	0.16	0.05
Pomacentridae	0.66	17.50	5.07	0.08			4.66	23.31	6.94
Mugilidae			0.13	0.07			0.04	0.20	0.06
Sphyraenidae		0.33	0.63	0.16			0.22	1.12	0.33
Labridae	3.53	4.30	0.14	0.43	1.28		1.94	9.68	2.88
Scaridae				0.07	0.56		0.13	0.63	0.19
Opistognathidae	0.34	0.15		0.07			0.11	0.55	0.17
Dactyloscopidae		0.15	0.82				0.19	0.97	0.29
Tripterygiidae	16.35	15.78	14.36	0.24			9.35	46.74	13.93
Blenniidae	8.18	6.98	0.63	0.16			3.19	15.95	4.75
Gobiidae	16.35	25.55	0.85	0.56	0.27		8.72	43.58	12.98
Microdesmidae	0.94	1.50	0.28				0.55	2.73	0.81
Acanthuridae				1.15	0.62		0.35	1.76	0.53
Gempylidae				0.08	0.07		0.03	0.15	0.05
Scombridae	0.15		0.73	0.46	0.95		0.46	2.29	0.68
Pleuronectiformes					0.19		0.04	0.19	0.06
Achiridae				0.09			0.02	0.09	0.03
Bothidae					0.09		0.02	0.09	0.03
Balistidae					0.07		0.01	0.07	0.02
Monacanthidae	0.47			0.09			0.11	0.56	0.17
Tetraodontiformes	3.15	2.19	0.28				1.12	5.62	1.67
Tetraodontidae			0.47	0.08	0.27		0.16	0.82	0.24
Unidentified	42.71	40.07	15.22	1.77	2.10		20.37	101.86	30.35
PreflexionTotal	128.34	132.56	51.17	11.34	12.25		67.13	335.65	100.00

Appendix I (Cont.)

March 21	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**	**Abund.**
Postflexion									
Engraulidae	0.34						0.07	0.34	1.39
Gonostomatidae				0.37	0.35		0.14	0.72	2.96
Astronesthidae					0.09		0.02	0.09	0.36
Myctophidae			0.13	0.23	0.39		0.15	0.75	3.08
Bythitidae			0.14				0.03	0.14	0.58
Callionymidae	0.67		0.11	0.45			0.25	1.23	5.08
Belonidae			0.13				0.03	0.13	0.53
Exocoetidae			0.14				0.03	0.14	0.58
Holocentridae				0.09	0.09		0.03	0.17	0.72
Syngnathidae	0.34	1.20					0.31	1.54	6.34
Scorpaenidae				0.07			0.01	0.07	0.28
Serranidae				0.45	0.32		0.15	0.76	3.14
Apogonidae					0.18		0.04	0.18	0.75
Carangidae					0.07		0.01	0.07	0.31
Lutjanidae			0.11	0.17	0.09		0.07	0.37	1.54
Gerreidae			2.99				0.60	2.99	12.32
Haemulidae	0.30	0.17	0.13		0.09		0.14	0.69	2.84
Sparidae	0.30	0.20					0.10	0.50	2.05
Mullidae			0.77				0.15	0.77	3.18
Pomacanthidae					0.09		0.02	0.09	0.38
Pomacentridae			0.27		0.17		0.09	0.44	1.81
Mugilidae		0.17		0.16			0.07	0.33	1.34
Sphyraenidae		0.31	0.65	0.08			0.21	1.04	4.27
Labridae			0.14	0.36	0.42		0.18	0.92	3.80
Scaridae				0.31	0.19		0.10	0.49	2.03
Dactyloscopidae			1.16				0.23	1.16	4.79
Tripterygiidae	0.17	0.67	4.19				1.01	5.04	20.74
Chaenopsidae			0.57				0.11	0.57	2.34
Blenniidae	0.15		0.14				0.06	0.29	1.21
Gobiidae			0.14	0.96	0.36		0.29	1.47	6.05
Microdesmidae			0.28				0.06	0.28	1.17
Acanthuridae				0.07			0.01	0.07	0.28
Gempylidae				0.15			0.03	0.15	0.63
Bothidae					0.09		0.02	0.09	0.36
Balistidae					0.09		0.02	0.09	0.38
Monacanthidae					0.09		0.02	0.09	0.36
Postflexion Total	2.27	2.71	12.22	3.91	3.17		4.86	24.28	100.00
Total	130.61	135.27	63.39	15.25	15.42		71.99		

Appendix I (Cont.)

April 3 FAMILY	3M Abund.	4M Abund.	5M Abund.	6M Abund.	9M Abund.	12M Abund.	Mean Abund.	Total Abund.	% of Total Abund.
Preflexion									
Nemichthyidae		0.30		0.14		0.14	0.10	0.58	0.15
Clupeiformes	0.87						0.15	0.87	0.22
Clupeidae	13.50	10.37	2.44				4.38	26.31	6.74
Engraulidae	23.54	13.23	3.77	0.23			6.79	40.77	10.45
Gonostomatidae				0.38	0.39	0.76	0.25	1.53	0.39
Sternoptychidae						0.14	0.02	0.14	0.04
Phosichthyidae				1.16	0.27	0.55	0.33	1.99	0.51
Astronesthidae						0.14	0.02	0.14	0.04
Myctophidae	0.15	0.15	1.28	14.45	11.05	8.43	5.92	35.49	9.10
Paralepididae					0.09	0.14	0.04	0.23	0.06
Scoperlarchidae				0.38		0.14	0.09	0.53	0.13
Bregmacerotidae						0.14	0.02	0.14	0.04
Ophidiidae				0.14		0.13	0.04	0.27	0.07
Carapidae				0.38			0.06	0.38	0.10
Callionymidae	0.53			0.28			0.14	0.81	0.21
Belonidae						0.13	0.02	0.13	0.03
Hemiramphidae			0.17	0.38			0.09	0.55	0.14
Holocentridae				0.14	1.36		0.25	1.50	0.38
Fistularidae			0.32	0.13			0.08	0.45	0.12
Scorpaenidae						0.25	0.04	0.25	0.06
Serranidae	1.53	0.44	0.79	0.74	1.56	0.61	0.95	5.67	1.45
Apogonidae				0.49	0.47		0.16	0.97	0.25
Malacanthidae		0.15					0.02	0.15	0.04
Carangidae	0.15	0.13		0.40	1.73	0.39	0.47	2.80	0.72
Coryphaenidae		0.30			0.29	0.27	0.14	0.85	0.22
Lutjanidae	1.31	3.35	5.39	2.30	0.40	0.54	2.21	13.28	3.40
Gerreidae	0.27		0.99	0.12			0.23	1.38	0.35
Haemulidae	5.76	2.04	0.50	0.60			1.48	8.89	2.28
Sparidae	0.26	0.72	0.83				0.30	1.81	0.46
Sciaenidae	0.29	0.30	1.77	0.92			0.55	3.28	0.84
Mullidae					1.45		0.24	1.45	0.37
Kyphosidae	0.27						0.05	0.27	0.07
Pomacanthidae					0.19		0.03	0.19	0.05
Pomacentridae	1.98	4.54	7.67	5.77	0.67	0.23	3.48	20.86	5.34
Mugilidae	0.13						0.02	0.13	0.03
Sphyraenidae	0.52		0.16	0.89	1.63		0.53	3.21	0.82
Labridae	0.51	5.12	8.95	4.75	1.03	0.38	3.45	20.73	5.31
Scaridae				0.26	0.37	0.13	0.13	0.75	0.19
Opistognathidae	0.15		0.32				0.08	0.46	0.12
Dactyloscopidae		0.13	0.66				0.13	0.79	0.20
Tripterygiidae	3.08	10.33	22.55	1.05			6.17	37.00	9.48
Chaenopsidae			0.16				0.03	0.16	0.04
Blenniidae	0.78	1.90	0.97				0.61	3.66	0.94
Eleotridae						0.14	0.02	0.14	0.04
Gobiidae	13.43	13.28	13.51	9.89	0.58	2.18	8.81	52.86	13.55
Microdesmidae	1.83	0.43	1.12	0.37			0.63	3.76	0.96
Acanthuridae		0.13	0.17	0.78		0.39	0.25	1.47	0.38
Gempylidae					0.19	0.25	0.07	0.44	0.11
Scombridae	1.61		0.16	1.03	1.57	0.49	0.81	4.86	1.24
Tetragonuridae		0.15			0.10	0.29	0.09	0.53	0.14
Pleuronectiformes				0.14			0.02	0.14	0.04
Achiridae				0.28			0.05	0.28	0.07
Balistidae	0.13			0.12	0.10		0.06	0.35	0.09
Monacanthidae	0.26	0.13	0.17	0.13	0.10		0.13	0.78	0.20
Ostracidae	0.13						0.02	0.13	0.03
Tetraodontiformes	0.69		3.88	2.36			1.16	6.93	1.78
Tetraodontidae	1.05	3.67		0.12		0.13	0.83	4.96	1.27
Unidentified	19.50	13.48	9.70	21.99	3.29	2.83	11.80	70.80	18.14
PreflexionTotal	94.20	84.76	88.38	73.68	28.88	20.34	65.04	390.25	100.00

Appendix I (Cont.)

April 3 FAMILY	3M Abund.	4M Abund.	5M Abund.	6M Abund.	9M Abund.	12M Abund.	Mean Abund.	Total Abund.	% of Total Abund.
Postflexion									
Clupeidae	0.26	5.09	0.65				1.00	6.01	10.17
Engraulidae	0.13	1.62	0.49				0.37	2.24	3.80
Gonostomatidae		0.13		0.23	0.68	2.62	0.61	3.66	6.21
Phosichthyidae						0.39	0.07	0.39	0.67
Chauliodontidae				0.13			0.02	0.13	0.21
Astronesthidae					0.10	0.14	0.04	0.24	0.41
Notosudidae					0.20		0.03	0.20	0.34
Myctophidae	0.13		0.32	1.17	0.58	0.92	0.52	3.13	5.30
Paralepididae					0.10	0.12	0.04	0.22	0.37
Bythitidae		0.28	1.31				0.26	1.59	2.69
Callionymidae				0.64			0.11	0.64	1.08
Belonidae	0.12						0.02	0.12	0.21
Exocoetidae				0.12			0.02	0.12	0.20
Holocentridae					0.09		0.02	0.09	0.15
Syngnathidae	0.13	0.44	0.17	0.13	0.10		0.16	0.96	1.63
Scorpaenidae				0.13			0.02	0.13	0.21
Serranidae				0.14	0.19	0.14	0.08	0.47	0.80
Apogonidae	0.27				0.29		0.09	0.56	0.94
Carangidae	0.15				0.38		0.09	0.53	0.89
Lutjanidae	0.39	0.41	0.16	0.27	0.10		0.22	1.33	2.25
Gerreidae	0.66	0.53	0.99	0.12			0.38	2.30	3.90
Haemulidae	0.64	0.27	0.17	0.12			0.20	1.18	2.00
Sparidae	0.39	0.28	0.17				0.14	0.83	1.41
Sciaenidae		0.13	0.17				0.05	0.30	0.51
Mullidae				0.14	0.10		0.04	0.24	0.41
Chaetodontidae				0.12			0.02	0.12	0.20
Pomacanthidae				0.13			0.02	0.13	0.21
Pomacentridae				0.13		0.14	0.04	0.27	0.46
Sphyraenidae			0.16	0.12	0.20		0.08	0.47	0.80
Labridae				0.23	0.10	0.92	0.21	1.25	2.12
Scaridae					0.49	0.37	0.14	0.85	1.44
Opistognathidae	0.15		0.17				0.05	0.31	0.53
Dactyloscopidae		0.30					0.05	0.30	0.50
Tripterygiidae	0.26	1.53	7.56				1.56	9.35	15.83
Chaenopsidae		0.96	0.16				0.19	1.12	1.89
Blenniidae			0.16				0.03	0.16	0.27
Eleotridae				0.24			0.04	0.24	0.41
Gobiidae	4.53	1.67	3.61	1.33	0.19	0.29	1.94	11.62	19.68
Microdesmidae	0.13	0.43	2.12	0.48	0.10		0.54	3.26	5.53
Acanthuridae					0.28		0.05	0.28	0.48
Gempylidae						0.26	0.04	0.26	0.44
Scombridae					0.68		0.11	0.68	1.16
Bothidae				0.39			0.07	0.39	0.66
Monacanthidae		0.15					0.02	0.15	0.25
Tetraodontidae		0.13			0.10		0.04	0.23	0.39
Postflexion Total	8.34	14.35	18.52	6.48	5.05	6.31	9.84	59.05	100.00
Total	102.53	99.12	106.91	80.17	33.93	26.65	74.88		

Appendix I (Cont.)

April 9	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.
Preflexion									
Congridae				0.16			0.03	0.16	0.04
Ophichthidae				0.17			0.03	0.17	0.04
Clupeidae	8.91	14.63	0.95	2.64			4.52	27.14	6.23
Engraulidae	25.77	0.64					4.40	26.41	6.06
Gonostomatidae			0.19	0.63	0.75	1.91	0.58	3.49	0.80
Phosichthyidae				0.34		0.28	0.10	0.62	0.14
Melanostomiidae						0.56	0.09	0.56	0.13
Myctophidae	0.17	0.35			5.27	12.74	3.09	18.53	4.25
Paralepididae						0.27	0.04	0.27	0.06
Evermannellidae						0.28	0.05	0.28	0.06
Bythitidae		0.35					0.06	0.35	0.08
Gobiesocidae	0.36						0.06	0.36	0.08
Callionymidae	13.40				0.30	0.28	2.33	13.98	3.21
Atherinidae	2.21	0.17					0.40	2.38	0.55
Hemiramphidae		0.17	0.24				0.07	0.41	0.09
Holocentridae				0.18	0.89		0.18	1.06	0.24
Syngnathidae	0.36						0.06	0.36	0.08
Dactylopteridae			0.19				0.03	0.19	0.04
Scorpaenidae			0.19		0.15		0.06	0.35	0.08
Serranidae	1.25			2.02	1.36		0.77	4.64	1.06
Priacanthidae					0.30	0.27	0.10	0.57	0.13
Apogonidae	0.84				0.30		0.19	1.14	0.26
Carangidae	1.17	0.17	0.24	0.31	2.09	1.09	0.85	5.07	1.16
Coryphaenidae		0.17					0.03	0.17	0.04
Lutjanidae	4.20	7.81	7.98	0.47	0.89	0.27	3.60	21.61	4.96
Haemulidae	5.47	0.99					1.08	6.46	1.48
Sparidae		0.17					0.03	0.17	0.04
Sciaenidae	2.93	0.33	0.24				0.58	3.50	0.80
Mullidae	0.17	0.16		0.33	1.36		0.34	2.02	0.46
Pomacanthidae						0.53	0.09	0.53	0.12
Pomacentridae	21.28	24.67	25.16	1.22	0.15		12.08	72.47	16.63
Mugilidae		0.17					0.03	0.17	0.04
Sphyraenidae	0.17	0.35	0.52	0.17	0.15		0.23	1.35	0.31
Labridae					1.65	0.56	0.37	2.21	0.51
Scaridae					0.89	2.44	0.56	3.33	0.76
Tripterygiidae	21.24	3.31	16.78	1.03	0.15		7.08	42.50	9.75
Blenniidae	0.51	0.84	0.52				0.31	1.86	0.43
Eleotridae			0.43				0.07	0.43	0.10
Gobiidae	37.87	4.89	5.49	2.51	0.76	2.17	8.95	53.69	12.32
Microdesmidae	5.47	0.33	0.95				1.12	6.75	1.55
Acanthuridae				0.81	0.30	0.81	0.32	1.92	0.44
Gempylidae					0.15		0.02	0.15	0.03
Scombridae		0.33		0.64	1.49	1.07	0.59	3.53	0.81
Tetragonuridae			0.32				0.05	0.32	0.07
Pleuronectiformes	0.34	0.17		0.18	0.15		0.14	0.84	0.19
Achiridae						0.28	0.05	0.28	0.06
Bothidae					0.29	0.81	0.18	1.10	0.25
Monacanthidae	0.36				0.15		0.09	0.51	0.12
Tetraodontiformes	2.88	3.09	10.06	0.35	0.30		2.78	16.69	3.83
Tetraodontidae			2.56		0.30	0.28	0.52	3.14	0.72
Diodontidae		0.17					0.03	0.17	0.04
Unidentified	27.52	9.31	21.33	9.16	7.97	4.09	13.23	79.39	18.22
PreflexionTotal	184.83	73.80	94.32	23.31	28.53	30.98	72.63	435.78	100.00

Appendix I (Cont.)

April 9	3M	4M	5M	6M	9M	12M	Mean	Total	% of Total
FAMILY	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.
Postflexion									
Clupeidae	0.33	11.21		0.16			1.95	11.70	13.40
Engraulidae	0.78	0.33					0.19	1.11	1.28
Gonostomatidae					0.30	1.91	0.37	2.22	2.54
Phosichthyidae					0.15	0.27	0.07	0.42	0.48
Melanostomiidae					0.15		0.03	0.15	0.17
Notosudidae					0.15		0.03	0.15	0.17
Myctophidae				0.33	0.90	2.69	0.65	3.93	4.50
Paralepididae				0.18			0.03	0.18	0.20
Evermannellidae						0.27	0.04	0.27	0.31
Bythitidae		0.52	1.17				0.28	1.69	1.94
Gobiesocidae			0.71				0.12	0.71	0.81
Callionymidae	0.78			1.00	1.37	0.55	0.62	3.69	4.23
Atherinidae				0.18			0.03	0.18	0.20
Belonidae	1.09						0.18	1.09	1.25
Hemiramphidae		0.51	0.24				0.12	0.74	0.85
Syngnathidae	1.17	0.16	0.71	0.18			0.37	2.22	2.54
Dactylopteridae							0.00	0.00	0.00
Scorpaenidae					0.15		0.03	0.15	0.17
Serranidae				4.37	1.51		0.98	5.89	6.74
Apogonidae				1.16	1.97		0.52	3.13	3.58
Carangidae	0.19		0.19	0.18	0.45		0.17	1.02	1.16
Coryphaenidae		0.33		0.16			0.08	0.49	0.56
Lutjanidae	1.45		2.02	0.51	0.60		0.76	4.58	5.24
Gerreidae		0.32	0.43	0.48			0.21	1.24	1.41
Haemulidae	0.19		0.43	0.16			0.13	0.78	0.90
Sparidae		0.17					0.03	0.17	0.20
Mullidae	0.19	0.16		0.17			0.09	0.52	0.60
Chaetodontidae						0.27	0.04	0.27	0.31
Pomacentridae			0.52	0.67	0.15	0.27	0.27	1.61	1.84
Mugilidae		0.17					0.03	0.17	0.20
Sphyraenidae				0.31	0.15		0.08	0.46	0.53
Labridae				0.17	1.21	1.09	0.41	2.47	2.83
Scaridae				0.31	1.96	1.10	0.56	3.38	3.87
Opistognathidae	0.39						0.06	0.39	0.45
Tripterygiidae		3.32	6.81	0.18			1.72	10.30	11.80
Labrisomidae	0.17						0.03	0.17	0.19
Blenniidae		0.35	0.67				0.17	1.02	1.16
Eleotridae		0.17	0.71				0.15	0.88	1.01
Gobiidae	5.07	0.96	2.30	3.66	1.36	0.27	2.27	13.61	15.59
Microdesmidae	1.14	0.49		0.18			0.30	1.81	2.08
Acanthuridae					0.15		0.02	0.15	0.17
Scombridae	0.17				0.30		0.08	0.46	0.53
Nomeidae					0.15	0.53	0.11	0.69	0.79
Bothidae					0.15	0.28	0.07	0.43	0.49
Paralichthyidae				0.17			0.03	0.17	0.19
Monacanthidae					0.30		0.05	0.30	0.35
Tetraodontidae				0.17			0.03	0.17	0.19
Postflexion Total	13.12	19.20	16.90	15.02	13.59	9.49	14.56	87.33	100.00
Total	197.95	92.99	111.22	38.34	42.12	40.47	87.18		

Appendix II: Taxonomic composition and abundance variation by station of fish larvae, off La Parguera, Puerto Rico, during Jan-24 to Apr-9, (1997) Station Total abundance by family and (%) of total are organized by taxa for pre-flexion and post-flexion larvae. Abundance are in (Larvae/100m^3)

Station 3 FAMILY	**3M 24-Jan**	**3M 31-Jan**	**3M 7-Feb**	**3M 19-Feb**	**3M 27-Feb**	**3M 6-Mar**	**3M 14-Mar**	**3M 21-Mar**	**3M 3-Apr**	**3M 9-Apr**	**Total Abund.**	**% of Total**
Preflexion												
Congridae												
Muraenidae												
Ophichthyidae												
Nemichthyidae												
Clupeiformes	2.23	1.97				1.28		0.85	0.87		7.21	0.78
Clupeidae	0.26	5.04		0.21	0.06	0.59		0.51	13.50	8.91	29.09	3.13
Engraulidae	3.75	0.54	19.70	15.50	6.12	9.91	19.90	12.48	23.54	25.77	137.22	14.78
Gonostomatidae												
Sternoptychidae												
Phosichthyidae												
Chauliodontidae												
Astronesthidae												
Melanostomidae												
Notosudidae												
Synodontidae												
Neoscopelidae												
Myctophidae		12.28			0.51	1.03			0.15	0.17	14.13	1.52
Paralepididae												
Evermanelidae												
Scoperlarchidae												
Bregmacerotidae												
Ophidiidae						0.18					0.18	0.02
Batrachoididae												
Bythitidae												
Lophiformes												
Carapidae												
Antennariidae												
Ogcocephalidae												
Gobiesocidae		0.18		0.45						0.36	0.99	0.11
Callionymidae	2.38			7.35	4.38	2.12	11.35	11.90	0.53	13.40	53.41	5.75
Atherinidae						0.17	0.20			2.21	2.58	0.28
Belonidae												
Hemiramphidae												
Exocoetidae												
Lampriformes												
Trachipterydae												
Holocentridae												
Aulostomidae												
Fistularidae												
Syngnathidae										0.36	0.36	0.04
Dactylopteridae												
Scorpaenidae												
Triglidae												
Serranidae	2.54	0.17	2.99			0.36	1.55	0.45	1.53	1.25	10.85	1.17
Priacanthidae												
Apogonidae							0.72			0.84	1.57	0.17
Malacanthidae												
Echeneidae								0.34			0.34	0.04
Carangidae	0.93	0.53					0.36		0.15	1.17	3.14	0.34
Coryphaenidae												
Bramidae												
Lutjanidae	0.22						0.20	1.57	1.31	4.20	7.49	0.81
Gerreidae						0.36			0.27		0.64	0.07
Haemulidae	1.50		3.03			0.71	1.93	1.51	5.76	5.47	19.91	2.14
Sparidae	0.96				0.45	0.17		1.21	0.26		3.05	0.33
Sciaenidae		0.69	0.39	0.68	5.86	1.30	2.08	4.69	0.29	2.93	18.93	2.04
Mullidae										0.17	0.17	0.02
Kyphosidae							0.36		0.27		0.63	0.07

Appendix II (Cont.): Station 3

Chaetodontidae						0.17					0.17	0.02
Pomacanthidae												
Pomacentridae	2.65	7.64	12.38	0.21	0.93	3.44	4.01	0.66	1.98	21.28	55.18	5.94
Mugilidae				4.79					0.13		4.92	0.53
Sphyraenidae				0.45			0.18		0.52	0.17	1.32	0.14
Polynemidae							0.54				0.54	0.06
Labridae	2.10	0.31	1.45	0.45		0.50	0.98	3.53	0.51		9.83	1.06
Scaridae												
Opistognathidae					0.06	0.59		0.34	0.15		1.13	0.12
Dactyloscopidae												
Tripterygiidae	3.39	4.20	3.60	12.92	2.18	5.99	11.18	16.35	3.08	21.24	84.14	9.06
Chaenopsidae												
Labrisomidae						0.26	0.20				0.46	0.05
Blenniidae	0.85	0.97	0.39	0.21			0.20	8.18	0.78	0.51	12.11	1.30
Eleotridae												
Gobiidae	11.05	9.96	2.96	20.91	4.89	8.62	28.91	16.35	13.43	37.87	154.95	16.69
Microdesmidae	0.26	0.90	0.82	2.20		0.62	2.80	0.94	1.83	5.47	15.85	1.71
Acanthuridae						0.26					0.26	0.03
Gempylidae												
Trichiuridae												
Scombridae		0.35						0.15	1.61		2.11	0.23
Nomeidae												
Tetragonuridae												
Pleuronectiformes	0.22	0.80	0.71	2.97	3.11		0.41			0.34	8.55	0.92
Achiridae												
Bothidae												
Paralichthyidae	0.26										0.26	0.03
Balistidae	1.07								0.13		1.20	0.13
Monacanthidae	0.28						0.18	0.47	0.26	0.36	1.56	0.17
Ostracidae									0.13		0.13	0.01
Tetraodontiformes	3.24	3.52	1.51	0.66		0.26	0.41	3.15	0.69	2.88	16.32	1.76
Tetraodontidae									1.05		1.05	0.11
Diodontidae		0.13									0.13	0.01
Molidae												
Unidentified	40.87	27.46	29.81	11.75	2.60	9.93	32.23	42.71	19.50	27.52	244.39	26.32
	81.04	77.64	79.76	81.71	31.15	48.81	120.93	128.34	94.20	184.83	928.41	100.00
Postflexion												
Muraenidae												
Clupeidae	0.26								0.26	0.33	0.86	1.91
Engraulidae	0.43	0.46	0.20	0.70		0.51	1.21	0.34	0.13	0.78	4.76	10.60
Gonostomatidae												
Phosichthyidae												
Stomiidae												
Chauliodontidae												
Astronesthidae												
Melanostomiidae												
Notosudidae												
Synodontidae												
Neoscopelidae												
Myctophidae		0.17	0.25						0.13		0.55	1.22
Paralepididae												
Evermanellidae												
Bregmacerotidae												
Ophidiidae												
Bythitidae												
Gobiesocidae												
Callionymidae				1.52	0.46	0.26		0.67		0.78	3.69	8.22
Atherinidae												
Belonidae									0.12	1.09	1.21	2.71
Hemiramphidae		0.13			0.40		0.18				0.70	1.57
Exocoetidae												

Appendix II (Cont.): Station 3

Holocentridae							0.39				0.39	0.86
Syngnathidae	0.43	1.40	1.44			0.84	0.81	0.34	0.13	1.17	6.56	14.62
Dactylopteridae												
Scorpaenidae												
Serranidae												
Grammistidae												
Apogonidae							0.72		0.27		1.00	2.22
Carangidae									0.15	0.19	0.34	0.76
Coryphaenidae												
Bramidae												
Lutjanidae	0.22								0.39	1.45	2.06	4.58
Gerreidae					0.46	0.18	0.21		0.66		1.52	3.38
Haemulidae	0.22						0.36	0.30	0.64	0.19	1.71	3.81
Sparidae	0.83				0.40	0.17	0.20	0.30	0.39		2.29	5.10
Sciaenidae												
Mullidae										0.19	0.19	0.43
Chaetodontidae												
Pomacanthidae												
Pomacentridae												
Mugilidae						0.26					0.26	0.57
Sphyraenidae												
Polynemidae							0.57				0.57	1.26
Labridae												
Scaridae	0.65										0.65	1.45
Opistognathidae						0.35			0.15	0.39	0.88	1.97
Dactyloscopidae												
Tripterygiidae	1.22	0.13				0.26		0.17	0.26		2.03	4.51
Labrisomidae										0.17	0.17	0.38
Chaenopsidae												
Blenniidae				0.21				0.15			0.36	0.81
Eleotridae												
Gobiidae				0.21		0.53	0.18		4.53	5.07	10.52	23.45
Microdesmidae							0.18		0.13	1.14	1.45	3.24
Acanthuridae												
Siganidae												
Gempylidae												
Scombridae										0.17	0.17	0.37
Nomeidae												
Tetragonuridae												
Achiridae												
Bothidae												
Paralichthyidae												
Balistidae												
Monacanthidae												
Tetraodontidae												
Diodontidae												
Abund postflexion	4.26	2.27	1.89	2.65	1.72	3.35	5.01	2.27	8.34	13.12	44.88	100.00
Abund total x sta.	85.30	79.91	81.65	84.36	32.87	52.16	125.93	130.61	102.53	197.95		

Appendix II (Cont.)

Station 4 FAMILY	4M 24-Jan	4M 31-Jan	4M 7-Feb	4M 19-Feb	4M 27-Feb	4M 6-Mar	4M 14-Mar	4M 21-Mar	4M 3-Apr	4M 9-Apr	Total Abund.	% of Total
Preflexion												
Congridae												
Muraenidae												
Ophichthyidae												
Nemichthyidae									0.30		0.30	0.04
Clupeiformes		0.20		5.29		7.89	2.50				15.89	2.10
Clupeidae		0.75	0.15		1.40	0.20	0.77	3.53	10.37	14.63	31.81	4.20
Engraulidae		5.49	0.69	11.74		1.93	5.20	3.52	13.23	0.64	42.45	5.60
Gonostomatidae		0.18		0.63		0.20					1.01	0.13
Sternoptychidae												
Phosichthyidae												
Chauliodontidae												
Astronesthidae												
Melanostomidae												
Notosudidae												
Synodontidae												
Neoscopelidae			0.15								0.15	0.02
Myctophidae		2.19	2.43		1.46	1.04			0.15	0.35	7.62	1.00
Paralepididae												
Evermanelidae												
Scoperlarchidae												
Bregmacerotidae												
Ophidiidae												
Batrachoididae												
Bythitidae		0.59								0.35	0.93	0.12
Lophiformes												
Carapidae												
Antennariidae												
Ogcocephalidae												
Gobiesocidae		1.38	0.30	0.20				0.29			2.17	0.29
Callionymidae				0.61			0.19				0.80	0.11
Atherinidae						0.20		0.15		0.17	0.52	0.07
Belonidae												
Hemiramphidae				0.55		0.22	0.39			0.17	1.33	0.18
Exocoetidae												
Lampriformes												
Trachipterydae												
Holocentridae								0.15			0.15	0.02
Aulostomidae												
Fistularidae												
Syngnathidae		0.18	0.16								0.34	0.04
Dactylopteridae												
Scorpaenidae												
Triglidae												
Serranidae		2.48	0.14	0.35	8.83	1.16	0.39		0.44		13.80	1.82
Priacanthidae												
Apogonidae												
Malacanthidae									0.15		0.15	0.02
Echeneidae												
Carangidae			0.14				0.40	0.60	0.13	0.17	1.45	0.19
Coryphaenidae						0.52			0.30	0.17	0.99	0.13
Bramidae												
Lutjanidae		3.19			0.31	0.57	8.79	2.26	3.35	7.81	26.28	3.47
Gerreidae			0.07	3.18	0.77						4.02	0.53
Haemulidae		2.73			0.77	1.52	3.51	6.47	2.04	0.99	18.02	2.38
Sparidae								0.15	0.72	0.17	1.04	0.14
Sciaenidae						2.18	0.58	0.81	0.30	0.33	4.20	0.55
Mullidae		0.20	0.31	0.39		1.46		0.15		0.16	2.67	0.35
Kyphosidae												

Appendix II (Cont.): Station 4

Chaetodontidae											
Pomacanthidae											
Pomacentridae	7.57	3.53	1.82	5.21	2.11	14.88	17.50	4.54	24.67	81.83	10.79
Mugilidae			0.79						0.17	0.96	0.13
Sphyraenidae	0.40	0.82	0.20	1.15	0.37		0.33		0.35	3.63	0.48
Polynemidae											
Labridae	0.38	0.47		0.26		0.77	4.30	5.12		11.30	1.49
Scaridae	0.40									0.40	0.05
Opistognathidae					0.57		0.15			0.72	0.09
Dactyloscopidae							0.15	0.13		0.28	0.04
Tripterygiidae	34.40	13.06	17.65	22.74	6.55	12.94	15.78	10.33	3.31	136.75	18.04
Chaenopsidae											
Labrisomidae											
Blenniidae	0.64	0.29	0.20	4.10	2.18	0.96	6.98	1.90	0.84	18.10	2.39
Eleotridae											
Gobiidae	24.13	0.38	9.27	2.42	0.60	4.82	25.55	13.28	4.89	85.33	11.25
Microdesmidae		0.23	0.62	3.67	1.91	2.12	1.50	0.43	0.33	10.81	1.43
Acanthuridae								0.13	0.00	0.13	0.02
Gempylidae											
Trichiuridae					0.17					0.17	0.02
Scombridae		1.78		0.31					0.33	2.43	0.32
Nomeidae	0.18			0.32		0.40				0.90	0.12
Tetragonuridae								0.15		0.15	0.02
Pleuronectiformes	0.76	0.07	0.21	0.51	0.20	0.19			0.17	2.12	0.28
Achiridae											
Bothidae											
Paralichthyidae											
Balistidae											
Monacanthidae								0.13		0.13	0.02
Ostracidae					0.22					0.22	0.03
Tetraodontiformes	3.55	1.93	0.37	0.94		1.94	2.19		3.09	14.02	1.85
Tetraodontidae			0.42		1.12			3.67		5.21	0.69
Diodontidae									0.17	0.17	0.02
Molidae											
Unidentified	41.49	6.13	13.49	41.31	7.90	31.08	40.07	13.48	9.31	204.28	26.95
	133.48	33.25	67.97	96.49	43.01	92.81	132.56	84.76	73.80	758.12	100.00
Postflexion											
Muraenidae											
Clupeidae		0.15				0.19		5.09	11.21	16.65	26.08
Engraulidae	0.18		0.39		0.22	1.17		1.62	0.33	3.92	6.15
Gonostomatidae	0.18							0.13		0.31	0.49
Phosichthyidae											
Stomiidae											
Chauliodontidae											
Astronesthidae											
Melanostomiidae											
Notosudidae											
Synodontidae											
Neoscopelidae											
Myctophidae		1.50								1.50	2.35
Paralepididae											
Evermanellidae											
Bregmacerotidae											
Ophidiidae					0.17					0.17	0.27
Bythitidae	0.79	0.22				0.59		0.28	0.52	2.39	3.75
Gobiesocidae	0.20	0.14								0.35	0.54
Callionymidae											
Atherinidae											
Belonidae					0.20					0.20	0.31
Hemiramphidae						0.58			0.51	1.09	1.70
Exocoetidae											

Appendix II (Cont.): Station 4

Holocentridae											
Syngnathidae	2.63	0.07	0.39		0.20	0.39	1.20	0.44	0.16	5.48	8.58
Dactylopteridae											
Scorpaenidae											
Serranidae											
Grammistidae											
Apogonidae						0.40				0.40	0.62
Carangidae											
Coryphaenidae		0.15							0.33	0.49	0.77
Bramidae											
Lutjanidae	0.20					0.40		0.41		1.01	1.58
Gerreidae		0.31	0.90	1.65		0.39		0.53	0.32	4.11	6.43
Haemulidae	0.98			0.31	0.35	0.39	0.17	0.27		2.46	3.86
Sparidae					0.17		0.20	0.28	0.17	0.83	1.29
Sciaenidae								0.13		0.13	0.21
Mullidae			0.21						0.16	0.37	0.58
Chaetodontidae											
Pomacanthidae											
Pomacentridae											
Mugilidae							0.17		0.17	0.34	0.53
Sphyraenidae		0.15					0.31			0.47	0.73
Polynemidae											
Labridae											
Scaridae											
Opistognathidae					0.17					0.17	0.27
Dactyloscopidae								0.30		0.30	0.46
Tripterygiidae	3.46	0.31		0.96	0.17	1.18	0.67	1.53	3.32	11.60	18.18
Labrisomidae				0.63						0.63	0.99
Chaenopsidae				0.32				0.96		1.28	2.00
Blenniidae	0.18								0.35	0.53	0.83
Eleotridae									0.17	0.17	0.27
Gobiidae	0.18	0.07	0.62		0.20	0.19		1.67	0.96	3.89	6.10
Microdesmidae			0.41		0.40	0.39		0.43	0.49	2.11	3.31
Acanthuridae											
Siganidae											
Gempylidae											
Scombridae											
Nomeidae											
Tetragonuridae						0.19				0.19	0.30
Achiridae											
Bothidae											
Paralichthyidae											
Balistidae											
Monacanthidae								0.15		0.15	0.23
Tetraodontidae								0.13		0.13	0.21
Diodontidae											
Abund postflexion	8.98	3.09	2.93	3.87	2.26	6.42	2.71	14.35	19.20	63.83	100.00
Abund total x sta.	142.46	36.35	70.90	100.37	45.27	99.23	135.27	99.12	92.99		

Appendix II (Cont.)

Station 5 FAMILY	5M 24-Jan	5M 31-Jan	5M 7-Feb	5M 19-Feb	5M 27-Feb	5M 6-Mar	5M 14-Mar	5M 21-Mar	5M 3-Apr	5M 9-Apr	Total Abund.	% of Total
Preflexion												
Congridae												
Muraenidae												
Ophichthyidae												
Nemichthyidae												
Clupeiformes	0.00		0.59	10.45		0.94	0.54				12.53	1.96
Clupeidae	0.00			0.28		0.91	0.61	0.27	2.44	0.95	5.46	0.86
Engraulidae	1.59		0.91	0.56		0.17	3.39	0.11	3.77		10.52	1.65
Gonostomatidae	0.00	0.19						0.13		0.19	0.51	0.08
Sternoptychidae												
Phosichthyidae												
Chauliodontidae												
Astronesthidae												
Melanostomidae												
Notosudidae												
Synodontidae												
Neoscopelidae												
Myctophidae	0.23	13.51	2.05	2.53	4.62	3.27		0.65	1.28		28.12	4.41
Paralepididae												
Evermanelidae												
Scoperlarchidae												
Bregmacerotidae												
Ophidiidae												
Batrachoididae												
Bythitidae		0.96	1.86				0.18	0.14			3.14	0.49
Lophiformes			0.37								0.37	0.06
Carapidae												
Antennariidae												
Ogcocephalidae												
Gobiesocidae		0.58	0.23		0.42						1.23	0.19
Callionymidae					0.10			0.13			0.23	0.04
Atherinidae												
Belonidae												
Hemiramphidae									0.17	0.24	0.40	0.06
Exocoetidae												
Lampriformes												
Trachipterydae												
Holocentridae					0.22		0.40	0.26			0.89	0.14
Aulostomidae												
Fistularidae						0.17			0.32		0.50	0.08
Syngnathidae												
Dactylopteridae										0.19	0.19	0.03
Scorpaenidae			0.18							0.19	0.38	0.06
Triglidae												
Serranidae	5.18		0.30		0.63	0.38	0.57	0.66	0.79		8.50	1.33
Priacanthidae												
Apogonidae												
Malacanthidae												
Echeneidae												
Carangidae		0.37	0.37			0.17		1.24		0.24	2.38	0.37
Coryphaenidae		0.41						0.24			0.66	0.10
Bramidae												
Lutjanidae	0.46					0.34	2.14	0.49	5.39	7.98	16.81	2.63
Gerreidae				0.28	0.42			2.32	0.99		4.01	0.63
Haemulidae		0.21	0.38				1.04		0.50		2.11	0.33
Sparidae						0.38		0.24	0.83		1.45	0.23
Sciaenidae	0.58			0.32	0.42	0.72			1.77	0.24	4.05	0.63
Mullidae				0.32	4.32	0.56	0.56	4.66			10.43	1.63
Kyphosidae												

Appendix II (Cont.): Station 5

Chaetodontidae												
Pomacanthidae												
Pomacentridae		7.60	18.85	8.19	7.15	2.21	6.42	5.07	7.67	25.16	88.32	13.85
Mugilidae					0.42			0.13			0.55	0.09
Sphyraenidae	0.29		0.23		1.09	0.17		0.63	0.16	0.52	3.09	0.48
Polynemidae												
Labridae		0.21	0.18		0.22	0.38		0.14	8.95		10.08	1.58
Scaridae												
Opistognathidae			0.37			0.38			0.32		1.06	0.17
Dactyloscopidae					4.07	0.36	0.18	0.82	0.66		6.09	0.95
Tripterygiidae	4.43	10.41	11.35	12.30	12.87	10.81	26.51	14.36	22.55	16.78	142.36	22.32
Chaenopsidae						1.54	0.61		0.16		2.31	0.36
Labrisomidae					6.13						6.13	0.96
Blenniidae	2.03	0.97	0.15		0.42	1.06		0.63	0.97	0.52	6.75	1.06
Eleotridae						0.17				0.43	0.60	0.09
Gobiidae	23.36	5.56	2.06	2.29	1.50	2.60	5.18	0.85	13.51	5.49	62.39	9.78
Microdesmidae			0.18		0.97	0.38		0.28	1.12	0.95	3.89	0.61
Acanthuridae									0.17		0.17	0.03
Gempylidae												
Trichiuridae												
Scombridae		0.37	0.23		0.33			0.73	0.16		1.82	0.29
Nomeidae		1.74			0.21	0.34					2.29	0.36
Tetragonuridae							1.83			0.32	2.15	0.34
Pleuronectiformes	0.58		0.23	0.28	0.84	0.36	0.39				2.68	0.42
Achiridae			0.15								0.15	0.02
Bothidae												
Paralichthyidae												
Balistidae												
Monacanthidae						0.19			0.17		0.35	0.06
Ostracidae							0.36				0.36	0.06
Tetraodontiformes	2.20	2.13	1.36	0.92		0.55	1.41	0.28	3.88	10.06	22.79	3.57
Tetraodontidae	0.23				0.22	0.17	0.00	0.47		2.56	3.66	0.57
Diodontidae												
Molidae												
Unidentified	4.86	10.35	19.20	17.55	32.36	9.72	12.59	15.22	9.70	21.33	152.89	23.97
	46.03	55.57	61.75	56.28	79.97	39.39	64.91	51.17	88.38	94.32	637.77	100.00
Postflexion												
Muraenidae												
Clupeidae									0.65		0.65	0.66
Engraulidae	0.78					0.17	0.62		0.49		2.06	2.08
Gonostomatidae		0.19									0.19	0.19
Phosichthyidae												
Stomiidae												
Chauliodontidae												
Astronesthidae												
Melanostomiidae												
Notosudidae												
Synodontidae												
Neoscopelidae												
Myctophidae		1.16	0.48	0.63	0.45	0.17		0.13	0.32		3.34	3.36
Paralepididae												
Evermanellidae												
Bregmacerotidae												
Ophidiidae												
Bythitidae		1.35	0.71			0.72	0.59	0.14	1.31	1.17	5.99	6.03
Gobiesocidae						0.70				0.71	1.41	1.42
Callionymidae						0.36	0.21	0.11			0.68	0.69
Atherinidae												
Belonidae			0.15		1.09			0.13			1.37	1.38
Hemiramphidae	0.26					0.36				0.24	0.86	0.86
Exocoetidae						0.34	0.18	0.14			0.66	0.67

Appendix II (Cont.): Station 5

Holocentridae							0.18				0.18	0.18
Syngnathidae			0.23			0.34	0.18		0.17	0.71	1.63	1.64
Dactylopteridae												
Scorpaenidae												
Serranidae	1.01				0.42						1.43	1.44
Grammistidae												
Apogonidae	0.29		0.56		0.22						1.07	1.08
Carangidae										0.19	0.19	0.20
Coryphaenidae												
Bramidae												
Lutjanidae			0.15				0.18	0.11	0.16	2.02	2.62	2.64
Gerreidae					0.65	0.17		2.99	0.99	0.43	5.23	5.27
Haemulidae		0.21						0.13	0.17	0.43	0.93	0.94
Sparidae			0.18			0.19			0.17		0.54	0.54
Sciaenidae				0.63					0.17		0.80	0.80
Mullidae				1.23		0.19		0.77			2.19	2.21
Chaetodontidae												
Pomacanthidae												
Pomacentridae	0.69					0.19		0.27		0.52	1.67	1.68
Mugilidae						0.19					0.19	0.19
Sphyraenidae				0.28				0.65	0.16		1.09	1.09
Polynemidae												
Labridae			0.15	0.32				0.14			0.61	0.61
Scaridae												
Opistognathidae			0.59						0.17		0.76	0.76
Dactyloscopidae					0.67	0.34	0.18	1.16			2.36	2.37
Tripterygiidae	6.43	4.56	2.60	1.45	0.22	1.61	3.57	4.19	7.56	6.81	39.00	39.23
Labrisomidae			0.44		1.74						2.18	2.20
Chaenopsidae							1.01	0.57	0.16		1.74	1.75
Blenniidae		0.19						0.14	0.16	0.67	1.16	1.16
Eleotridae										0.71	0.71	0.71
Gobiidae	1.65	0.19	0.52	0.60	0.22	1.45	0.18	0.14	3.61	2.30	10.87	10.93
Microdesmidae	0.49		0.15					0.28	2.12		3.05	3.06
Acanthuridae												
Siganidae												
Gempylidae												
Scombridae												
Nomeidae												
Tetragonuridae												
Achiridae												
Bothidae												
Paralichthyidae												
Balistidae												
Monacanthidae												
Tetraodontidae												
Diodontidae												
Abund postflexion	11.61	7.84	6.92	5.14	5.69	7.49	7.08	12.22	18.52	16.90	99.41	100.00
Abund total x sta.	57.64	63.41	68.67	61.42	85.66	46.88	71.98	63.39	106.91	111.22		

Appendix II (Cont.)

Station 6 FAMILY	6M 24-Jan	6M 31-Jan	6M 7-Feb	6M 19-Feb	6M 27-Feb	6M 6-Mar	6M 14-Mar	6M 21-Mar	6M 3-Apr	6M 9-Apr	Total Abund.	% of Total
Preflexion												
Congridae										0.16	0.16	0.04
Muraenidae												
Ophichthyidae								0.09		0.17	0.25	0.07
Nemichthyidae	0.07		0.10						0.14		0.31	0.09
Clupeiformes				0.62							0.62	0.17
Clupeidae		0.12	0.05	0.51	1.23		0.12			2.64	4.68	1.30
Engraulidae			0.18	0.14		0.43			0.23		0.98	0.27
Gonostomatidae	0.07	1.12	0.22	0.46			0.51	0.50	0.38	0.63	3.89	1.08
Sternoptychidae												
Phosichthyidae		0.18	0.16			0.45			1.16	0.34	2.28	0.63
Chauliodontidae												
Astronesthidae												
Melanostomidae												
Notosudidae												
Synodontidae						0.15					0.15	0.04
Neoscopelidae												
Myctophidae	2.73	8.06	5.76	3.04	0.79	4.95	3.19	2.26	14.45		45.23	12.53
Paralepididae	0.07	0.10	0.11			0.15		0.50			0.94	0.26
Evermanelidae												
Scoperlarchidae									0.38		0.38	0.11
Bregmacerotidae			0.05			0.30					0.35	0.10
Ophidiidae	0.07	0.05						0.07	0.14		0.33	0.09
Batrachoididae			0.05								0.05	0.01
Bythitidae												
Lophiformes		0.05									0.05	0.01
Carapidae									0.38		0.38	0.11
Antennariidae							0.23				0.23	0.06
Ogcocephalidae		0.05									0.05	0.01
Gobiesocidae												
Callionymidae				0.47					0.28		0.75	0.21
Atherinidae												
Belonidae												
Hemiramphidae					0.40				0.38		0.78	0.22
Exocoetidae												
Lampriformes								0.08			0.08	0.02
Trachipterydae												
Holocentridae				0.14		0.63		0.15	0.14	0.18	1.24	0.34
Aulostomidae	0.19										0.19	0.05
Fistularidae									0.13		0.13	0.03
Syngnathidae												
Dactylopteridae		0.05									0.05	0.01
Scorpaenidae		0.06						0.07			0.13	0.04
Triglidae						0.15					0.15	0.04
Serranidae	0.87	0.13	0.42	0.61	0.42	0.65	0.69	0.68	0.74	2.02	7.23	2.00
Priacanthidae	0.30										0.30	0.08
Apogonidae									0.49		0.49	0.14
Malacanthidae												
Echeneidae												
Carangidae	0.14		0.38	0.18	0.20		0.49	0.88	0.40	0.31	2.97	0.82
Coryphaenidae	0.09		0.23			0.50		0.15			0.97	0.27
Bramidae		0.18									0.18	0.05
Lutjanidae	0.15	0.17	0.06	0.18	0.64	2.38		0.23	2.30	0.47	6.59	1.83
Gerreidae									0.12		0.12	0.03
Haemulidae					0.79	0.15	0.12		0.60		1.65	0.46
Sparidae												
Sciaenidae		0.29	0.06	0.18	1.38	0.94	0.12		0.92		3.90	1.08
Mullidae		0.05	0.06			0.60				0.33	1.04	0.29
Kyphosidae			0.12								0.12	0.03

Appendix II (Cont.): Station 6

Chaetodontidae	0.18							0.15			0.33	0.09
Pomacanthidae	0.09		0.05	0.18							0.32	0.09
Pomacentridae			0.51	3.67	10.62	0.44	0.12	0.08	5.77	1.22	22.42	6.21
Mugilidae	0.13		0.05		0.40			0.07			0.65	0.18
Sphyraenidae		0.63	0.11	0.98	0.22		0.95	0.16	0.89	0.17	4.12	1.14
Polynemidae												
Labridae	0.40	0.16	0.24	0.51	1.48	3.84	1.32	0.43	4.75		13.14	3.64
Scaridae	1.05	0.30		0.15				0.07	0.26		1.82	0.50
Opistognathidae	0.27	0.05						0.07			0.38	0.11
Dactyloscopidae												
Tripterygiidae	2.25	0.81		9.50	16.50	1.24	1.32	0.24	1.05	1.03	33.93	9.40
Chaenopsidae												
Labrisomidae					1.09						1.09	0.30
Blenniidae		0.04						0.16			0.20	0.05
Eleotridae					0.20						0.20	0.05
Gobiidae	0.45	0.16	0.34	6.97	29.07	1.90	0.23	0.56	9.89	2.51	52.08	14.42
Microdesmidae							0.41		0.37		0.78	0.22
Acanthuridae	0.08		0.15			0.15	0.53	1.15	0.78	0.81	3.65	1.01
Gempylidae		0.05	0.06					0.08			0.20	0.05
Trichiuridae												
Scombridae	0.31	0.56	2.31	0.18	0.82	0.92	2.03	0.46	1.03	0.64	9.26	2.56
Nomeidae		0.49	0.79			0.63	0.12				2.03	0.56
Tetragonuridae							0.26				0.26	0.07
Pleuronectiformes	0.28						0.41		0.14	0.18	1.01	0.28
Achiridae	0.07	0.04						0.09	0.28		0.47	0.13
Bothidae					0.79						0.79	0.22
Paralichthyidae			0.05								0.05	0.01
Balistidae									0.12		0.12	0.03
Monacanthidae								0.09	0.13		0.21	0.06
Ostracidae							0.12				0.12	0.03
Tetraodontiformes	0.05		0.21	0.18	1.68	0.30			2.36	0.35	5.14	1.42
Tetraodontidae				0.14			0.32	0.08	0.12		0.65	0.18
Diodontidae	0.08										0.08	0.02
Molidae												
Unidentified	4.69	3.84	1.13	19.75	39.83	10.69	2.43	1.77	21.99	9.16	115.27	31.92
	15.12	17.77	14.03	48.74	108.55	32.54	16.01	11.34	73.68	23.31	361.10	100.00
Postflexion												
Muraenidae												
Clupeidae		0.08								0.16	0.24	0.44
Engraulidae						0.21					0.21	0.39
Gonostomatidae	0.24	0.71	0.28	0.27				0.37	0.23		2.09	3.83
Phosichthyidae		0.16	0.06			0.30					0.52	0.95
Stomiidae						0.15					0.15	0.27
Chauliodontidae							0.46		0.13		0.59	1.08
Astronesthidae												
Melanostomiidae			0.05								0.05	0.09
Notosudidae												
Synodontidae												
Neoscopelidae		0.05									0.05	0.09
Myctophidae	0.62	1.12	1.85	0.18		1.16	0.26	0.23	1.17	0.33	6.93	12.68
Paralepididae		0.09					0.21			0.18	0.48	0.87
Evermanellidae												
Bregmacerotidae						0.15					0.15	0.27
Ophidiidae		0.05	0.11								0.16	0.30
Bythitidae						0.14					0.14	0.27
Gobiesocidae	0.07	0.10		0.14	0.22						0.53	0.97
Callionymidae	0.07	0.26	0.16	0.14	0.20	0.29	0.41	0.45	0.64	1.00	3.60	6.59
Atherinidae										0.18	0.18	0.32
Belonidae	0.05										0.05	0.09
Hemiramphidae		0.10									0.10	0.17
Exocoetidae		0.05							0.12		0.17	0.31

Appendix II (Cont.): Station 6

Holocentridae								0.09			0.09	0.16
Syngnathidae			0.06		0.40	0.21			0.13	0.18	0.97	1.78
Dactylopteridae												
Scorpaenidae		0.10				0.29		0.07	0.13		0.59	1.08
Serranidae	0.09	0.05	0.06	0.29	0.20	0.14		0.45	0.14	4.37	5.80	10.62
Grammistidae		0.04									0.04	0.07
Apogonidae	0.10				0.62					1.16	1.88	3.45
Carangidae	0.18		0.12							0.18	0.47	0.86
Coryphaenidae										0.16	0.16	0.29
Bramidae		0.09									0.09	0.17
Lutjanidae	0.07	0.04					0.37	0.17	0.27	0.51	1.41	2.59
Gerreidae				0.41		0.29	0.26		0.12	0.48	1.55	2.84
Haemulidae									0.12	0.16	0.27	0.50
Sparidae						0.21					0.21	0.39
Sciaenidae						0.14					0.14	0.27
Mullidae									0.14	0.17	0.31	0.57
Chaetodontidae	0.28								0.12		0.40	0.73
Pomacanthidae									0.13		0.13	0.23
Pomacentridae	0.05					0.21			0.13	0.67	1.06	1.94
Mugilidae			0.06					0.16			0.22	0.41
Sphyraenidae	0.09	0.05	0.06			0.15		0.08	0.12	0.31	0.87	1.58
Polynemidae												
Labridae	0.63	0.38	0.12			0.14		0.36	0.23	0.17	2.04	3.73
Scaridae	0.54	0.71	0.37	0.62		0.30	0.26	0.31		0.31	3.42	6.25
Opistognathidae Dactyloscopidae												
Tripterygiidae				0.56		0.51				0.18	1.25	2.28
Labrisomidae	0.05										0.05	0.09
Chaenopsidae												
Blenniidae	0.05			0.14							0.19	0.34
Eleotridae			0.06						0.24		0.31	0.56
Gobiidae	0.75	0.77	0.60	1.61	0.22	0.73	0.51	0.96	1.33	3.66	11.16	20.43
Microdesmidae						0.21			0.48	0.18	0.87	1.59
Acanthuridae						0.21		0.07			0.28	0.51
Siganidae												
Gempylidae								0.15			0.15	0.28
Scombridae	0.08	0.05	0.12			0.14					0.40	0.73
Nomeidae		0.05	0.14								0.19	0.34
Tetragonuridae												
Achiridae	0.12					0.30					0.42	0.77
Bothidae		0.05							0.39		0.44	0.81
Paralichthyidae										0.17	0.17	0.31
Balistidae												
Monacanthidae												
Tetraodontidae										0.17	0.17	0.31
Diodontidae	0.08										0.08	0.14
Abund postflexion	4.22	5.16	4.29	4.35	1.85	6.60	2.73	3.91	6.48	15.02	54.62	100.00
Abund total x sta.	19.34	22.93	18.32	53.09	110.40	39.14	18.75	15.25	80.17	38.34		

Appendix II (Cont.)

Station 9 FAMILY	9M 24-Jan	9M 31-Jan	9M 7-Feb	9M 19-Feb	9M 27-Feb	9M 6-Mar	9M 14-Mar	9M 21-Mar	9M 3-Apr	9M 9-Apr	Total Abund.	% of Total
Preflexion												
Congridae												
Muraenidae						0.17					0.17	0.08
Ophichthyidae						0.30		0.07			0.37	0.17
Nemichthyidae	0.08				0.21						0.29	0.13
Clupeiformes												
Clupeidae						0.18					0.18	0.08
Engraulidae						0.18	0.24				0.42	0.19
Gonostomatidae		0.39	0.36	1.51	0.14	0.64	0.99	0.62	0.39	0.75	5.80	2.62
Sternoptychidae												
Phosichthyidae			0.24						0.27		0.52	0.23
Chauliodontidae	0.17										0.17	0.08
Astronesthidae												
Melanostomidae												
Notosudidae				0.27							0.27	0.12
Synodontidae												
Neoscopelidae		0.12									0.12	0.06
Myctophidae	7.84	20.19	8.01	2.08	6.56	6.98	1.55	3.25	11.05	5.27	72.78	32.82
Paralepididae	0.08			0.67	1.00			0.19	0.09		2.02	0.91
Evermanelidae			0.24								0.24	0.11
Scoperlarchidae												
Bregmacerotidae												
Ophidiidae		0.14					0.21	0.18			0.53	0.24
Batrachoididae											0.00	0.00
Bythitidae						0.36					0.36	0.16
Lophiformes												
Carapidae												
Antennariidae							0.34				0.34	0.15
Ogcocephalidae												
Gobiesocidae							0.11				0.11	0.05
Callionymidae	0.11				0.43					0.30	0.84	0.38
Atherinidae												
Belonidae		0.12									0.12	0.06
Hemiramphidae												
Exocoetidae												
Lampriformes												
Trachipterydae												
Holocentridae							1.85	0.07	1.36	0.89	4.17	1.88
Aulostomidae												
Fistularidae												
Syngnathidae												
Dactylopteridae		0.50	0.12								0.62	0.28
Scorpaenidae	0.25			0.14	0.14					0.15	0.69	0.31
Triglidae							0.11				0.11	0.05
Serranidae	0.23				0.29	1.37	0.45	0.66	1.56	1.36	5.92	2.67
Priacanthidae							0.11			0.30	0.41	0.19
Apogonidae							0.11		0.47	0.30	0.88	0.40
Malacanthidae												
Echeneidae		0.27									0.27	0.12
Carangidae	0.18					2.16	1.72	0.26	1.73	2.09	8.13	3.67
Coryphaenidae						0.17	0.21	0.26	0.29		0.93	0.42
Bramidae												
Lutjanidae						1.59			0.40	0.89	2.88	1.30
Gerreidae				0.13			0.11				0.24	0.11
Haemulidae	0.08					2.01					2.08	0.94
Sparidae							0.13				0.13	0.06
Sciaenidae	0.17						0.13	0.07			0.37	0.17
Mullidae							0.21		1.45	1.36	3.02	1.36
Kyphosidae												

Appendix II (Cont.): Station 9

Chaetodontidae				0.14							0.14	0.07
Pomacanthidae								0.16	0.19		0.35	0.16
Pomacentridae						2.09	0.21		0.67	0.15	3.11	1.40
Mugilidae							0.52				0.52	0.23
Sphyraenidae	0.63	0.25	0.12		0.43	1.52	1.26		1.63	0.15	5.98	2.70
Polynemidae												
Labridae	0.58		0.12	0.70	0.72	0.89	2.29	1.28	1.03	1.65	9.26	4.17
Scaridae	1.97		0.31	0.56	3.88	0.17		0.56	0.37	0.89	8.70	3.92
Opistognathidae												
Dactyloscopidae												
Tripterygiidae	3.52					0.18	0.21			0.15	4.06	1.83
Chaenopsidae												
Labrisomidae												
Blenniidae							0.26				0.26	0.12
Eleotridae												
Gobiidae	0.28				0.14	0.18	0.51	0.27	0.58	0.76	2.73	1.23
Microdesmidae		0.28									0.28	0.13
Acanthuridae	0.66		0.12	0.14	0.50	0.17	0.11	0.62		0.30	2.63	1.18
Gempylidae		0.76	0.10				0.24	0.07	0.19	0.15	1.52	0.69
Trichiuridae												
Scombridae	0.25	3.28	0.46		0.29	1.17	1.01	0.95	1.57	1.49	10.45	4.71
Nomeidae	0.11	1.28	0.38	0.42	0.50	0.17					2.85	1.29
Tetragonuridae							0.21		0.10		0.31	0.14
Pleuronectiformes	0.22					0.18	0.10	0.19		0.15	0.84	0.38
Achiridae	0.25										0.25	0.11
Bothidae				0.14				0.09		0.29	0.53	0.24
Paralichthyidae												
Balistidae								0.07	0.10		0.17	0.08
Monacanthidae									0.10	0.15	0.25	0.11
Ostracidae												
Tetraodontiformes	0.32					0.48				0.30	1.11	0.50
Tetraodontidae			0.24				0.36	0.27		0.30	1.17	0.53
Diodontidae		0.25									0.25	0.11
Molidae							0.11				0.11	0.05
Unidentified	3.72	3.39	0.72	2.86	2.36	16.05	4.95	2.10	3.29	7.97	47.42	21.38
	21.68	31.23	11.55	9.78	17.59	39.38	20.91	12.25	28.88	28.53	221.78	100.00
Postflexion												
Muraenidae			0.27								0.27	0.55
Clupeidae												
Engraulidae												
Gonostomatidae		1.51	0.31	0.14	0.36	0.17		0.35	0.68	0.30	3.83	7.63
Phosichthyidae		0.12				0.34				0.15	0.62	1.23
Stomiidae												
Chauliodontidae												
Astronesthidae								0.09	0.10		0.19	0.38
Melanostomiidae						0.17	0.10			0.15	0.43	0.85
Notosudidae									0.20	0.15	0.35	0.70
Synodontidae												
Neoscopelidae												
Myctophidae	1.12	2.26	1.15	2.09	0.78	1.54	1.11	0.39	0.58	0.90	11.92	23.76
Paralepididae						0.18			0.10		0.28	0.56
Evermanellidae												
Bregmacerotidae												
Ophidiidae												
Bythitidae												
Gobiesocidae												
Callionymidae				0.13		0.48				1.37	1.98	3.95
Atherinidae												
Belonidae		0.12									0.12	0.25
Hemiramphidae		0.50	0.10								0.60	1.20
Exocoetidae												

Appendix II (Cont.): Station 9

Holocentridae								0.09	0.09		0.18	0.36
Syngnathidae				0.13					0.10		0.23	0.47
Dactylopteridae		0.12									0.12	0.25
Scorpaenidae					0.14		0.11			0.15	0.41	0.81
Serranidae	0.17		0.26		0.14	0.17		0.32	0.19	1.51	2.76	5.50
Grammistidae												
Apogonidae				0.13				0.18	0.29	1.97	2.57	5.12
Carangidae				0.27		0.17	0.24	0.07	0.38	0.45	1.58	3.15
Coryphaenidae		0.12					0.21				0.33	0.66
Bramidae				0.14							0.14	0.29
Lutjanidae					0.36		0.10	0.09	0.10	0.60	1.26	2.51
Gerreidae							0.10				0.10	0.21
Haemulidae						0.47		0.09			0.56	1.12
Sparidae												
Sciaenidae												
Mullidae									0.10		0.10	0.20
Chaetodontidae												
Pomacanthidae				0.14	0.14			0.09			0.38	0.76
Pomacentridae	0.17			0.14	0.14			0.17		0.15	0.78	1.55
Mugilidae							0.10				0.10	0.21
Sphyraenidae						0.18			0.20	0.15	0.53	1.05
Polynemidae												
Labridae	0.11		0.52		0.14		0.10	0.42	0.10	1.21	2.60	5.19
Scaridae			0.73		0.86	0.83		0.19	0.49	1.96	5.05	10.07
Opistognathidae												
Dactyloscopidae												
Tripterygiidae												
Labrisomidae						0.18					0.18	0.36
Chaenopsidae												
Blenniidae												
Eleotridae			0.24		0.36		0.11				0.71	1.42
Gobiidae	0.17			0.55		0.72	0.13	0.36	0.19	1.36	3.48	6.93
Microdesmidae									0.10		0.10	0.20
Acanthuridae	0.11	0.14			0.57				0.28	0.15	1.25	2.49
Siganidae											0.00	0.00
Gempylidae		0.37					0.11				0.48	0.96
Scombridae		0.12							0.68	0.30	1.11	2.21
Nomeidae			0.12	0.14			0.11			0.15	0.53	1.05
Tetragonuridae												
Achiridae												
Bothidae			0.26					0.09		0.15	0.50	0.99
Paralichthyidae												
Balistidae						0.17		0.09			0.26	0.53
Monacanthidae	0.11						0.13	0.09		0.30	0.63	1.25
Tetraodontidae					0.14	0.30			0.10		0.54	1.08
Diodontidae												
Abund postflexion	1.95	5.41	3.96	4.03	4.16	6.08	2.77	3.17	5.05	13.59	50.17	100.00
Abund total x sta.	23.63	36.64	15.51	13.81	21.74	45.46	23.68	15.42	33.93	42.12		

Appendix II (Cont.)

Station 12 FAMILY	12M 24-Jan	12M 31-Jan	12M 7-Feb	12M 19-Feb	12M 27-Feb	12M 6-Mar	12M 14-Mar	12M 21-Mar	12M 3-Apr	12M 9-Apr	Total Abund.	% of Total
Preflexion												
Congridae												
Muraenidae												
Ophichthyidae												
Nemichthyidae	0.30								0.14		0.45	0.25
Clupeiformes												
Clupeidae												
Engraulidae			0.14								0.14	0.08
Gonostomatidae		0.86	0.13	0.43	2.08	2.35			0.76	1.91	8.52	4.85
Sternoptychidae									0.14		0.14	0.08
Phosichthyidae		0.14	0.13		0.10				0.55	0.28	1.20	0.68
Chauliodontidae												
Astronesthidae									0.14		0.14	0.08
Melanostomidae				0.29						0.56	0.85	0.48
Notosudidae												
Synodontidae												
Neoscopelidae												
Myctophidae	5.28	40.96	4.93	10.60	5.35	4.89			8.43	12.74	93.19	53.05
Paralepididae	0.33		0.22	0.37		0.32			0.14	0.27	1.65	0.94
Evermanelidae										0.28	0.28	0.16
Scoperlarchidae									0.14		0.14	0.08
Bregmacerotidae									0.14		0.14	0.08
Ophidiidae									0.13		0.13	0.07
Batrachoididae												
Bythitidae												
Lophiformes												
Carapidae												
Antennariidae												
Ogcocephalidae												
Gobiesocidae												
Callionymidae					0.18	0.24				0.28	0.69	0.39
Atherinidae						0.15					0.15	0.09
Belonidae									0.13		0.13	0.07
Hemiramphidae			0.13								0.13	0.07
Exocoetidae	0.12										0.12	0.07
Lampriformes											0.00	0.00
Trachipterydae		0.15									0.15	0.08
Holocentridae	0.24		0.28	0.27	0.08						0.86	0.49
Aulostomidae												
Fistularidae												
Syngnathidae												
Dactylopteridae	0.09	0.15	0.13								0.37	0.21
Scorpaenidae				0.15	0.10				0.25		0.50	0.28
Triglidae					0.08						0.08	0.05
Serranidae	0.09		1.06	0.15	0.39				0.61		2.29	1.31
Priacanthidae										0.27	0.27	0.15
Apogonidae												
Malacanthidae												
Echeneidae		0.14									0.14	0.08
Carangidae			0.22	0.12	0.44	0.64			0.39	1.09	2.91	1.65
Coryphaenidae		0.57	0.37						0.27		1.21	0.69
Bramidae												
Lutjanidae						0.45			0.54	0.27	1.26	0.72
Gerreidae												
Haemulidae			0.13								0.13	0.07
Sparidae												
Sciaenidae												
Mullidae	0.12				0.52						0.64	0.36
Kyphosidae					0.08						0.08	0.05

Appendix II (Cont.): Station 12

Chaetodontidae				0.25	0.10						0.34	0.20
Pomacanthidae										0.53	0.53	0.30
Pomacentridae			0.13		0.10	0.32			0.23		0.77	0.44
Mugilidae												
Sphyraenidae	0.36	0.14	0.26	0.86	0.55	0.15					2.32	1.32
Polynemidae												
Labridae			0.28	0.58	0.76				0.38	0.56	2.54	1.45
Scaridae	0.18			0.15	0.88				0.13	2.44	3.77	2.15
Opistognathidae	0.12										0.12	0.07
Dactyloscopidae												
Tripterygiidae	0.74										0.74	0.42
Chaenopsidae												
Labrisomidae												
Blenniidae												
Eleotridae					0.10				0.14		0.24	0.14
Gobiidae	0.23	0.14	1.57	0.29					2.18	2.17	6.59	3.75
Microdesmidae					0.08						0.08	0.05
Acanthuridae	1.78			3.09	0.18				0.39	0.81	6.26	3.56
Gempylidae		0.43		0.12		0.15			0.25		0.95	0.54
Trichiuridae											0.00	0.00
Scombridae	0.12	8.02	0.36		0.76	1.49			0.49	1.07	12.30	7.00
Nomeidae			1.24			0.15					1.39	0.79
Tetragonuridae									0.29		0.29	0.16
Pleuronectiformes						0.33					0.33	0.19
Achiridae										0.28	0.28	0.16
Bothidae						0.24				0.81	1.05	0.60
Paralichthyidae												
Balistidae												
Monacanthidae												
Ostracidae												
Tetraodontiformes	0.28										0.28	0.16
Tetraodontidae									0.13	0.28	0.40	0.23
Diodontidae												
Molidae						0.17					0.17	0.09
Unidentified	0.83	1.40	1.83	1.62	1.31	0.95			2.83	4.09	14.86	8.46
	11.20	53.09	13.53	19.34	14.29	12.98			20.34	30.98	175.66	100
Postflexion												
Muraenidae			0.14								0.14	0.34
Clupeidae												
Engraulidae												
Gonostomatidae	0.32	1.28	0.14	0.29		0.55			2.62	1.91	7.12	17.33
Phosichthyidae				0.15					0.39	0.27	0.81	1.97
Stomiidae												
Chauliodontidae												
Astronesthidae				0.13					0.14		0.28	0.67
Melanostomiidae				0.12							0.12	0.30
Notosudidae												
Synodontidae					0.08						0.08	0.20
Neoscopelidae												
Myctophidae	0.79	1.70	4.69	1.19	0.80	1.74			0.92	2.69	14.53	35.37
Paralepididae	0.12								0.12		0.23	0.57
Evermanellidae										0.27	0.27	0.65
Bregmacerotidae												
Ophidiidae												
Bythitidae												
Gobiesocidae												
Callionymidae						0.40				0.55	0.95	2.30
Atherinidae												
Belonidae												
Hemiramphidae												
Exocoetidae	0.12										0.12	0.29

Appendix II (Cont.): Station 12

Holocentridae												
Syngnathidae												
Dactylopteridae												
Scorpaenidae												
Serranidae			0.27	0.13	0.08				0.14		0.62	1.52
Grammistidae												
Apogonidae			0.13								0.13	0.31
Carangidae				0.15	0.08						0.23	0.56
Coryphaenidae			0.13		0.16	0.15					0.44	1.07
Bramidae			0.14								0.14	0.34
Lutjanidae						0.15					0.15	0.37
Gerreidae	0.09				0.00						0.09	0.22
Haemulidae					0.10						0.10	0.24
Sparidae												
Sciaenidae												
Mullidae												
Chaetodontidae										0.27	0.27	0.65
Pomacanthidae											0.00	0.00
Pomacentridae	0.09								0.14	0.27	0.50	1.22
Mugilidae												
Sphyraenidae				0.15							0.15	0.36
Polynemidae												
Labridae	0.49	0.28		0.81	0.60	0.17			0.92	1.09	4.35	10.58
Scaridae	0.28		0.88	0.15					0.37	1.10	2.77	6.73
Opistognathidae												
Dactyloscopidae												
Tripterygiidae												
Labrisomidae												
Chaenopsidae												
Blenniidae												
Eleotridae			0.14			0.24					0.37	0.91
Gobiidae	0.09		0.69						0.29	0.27	1.33	3.25
Microdesmidae												
Acanthuridae		0.14	0.55								0.69	1.69
Siganidae	0.09										0.09	0.22
Gempylidae		0.28	0.09		0.18	0.15			0.26		0.97	2.35
Scombridae	0.09	0.43			0.08	0.24					0.83	2.03
Nomeidae			0.23	0.13	0.10					0.53	1.00	2.43
Tetragonuridae												
Achiridae												
Bothidae			0.22		0.10	0.15				0.28	0.75	1.82
Paralichthyidae												
Balistidae						0.15					0.15	0.37
Monacanthidae	0.09										0.09	0.22
Tetraodontidae												
Diodontidae	0.23										0.23	0.56
Abund postflexion	2.89	4.12	8.43	3.41	2.35	4.09			6.31	9.49	41.10	100.00
Abund total x sta.	14.10	57.21	21.96	22.75	16.64	17.07			26.65	40.47		