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Allyn B. Powell
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# Ichthyoplankton Adjacent to Live-Bottom Habitats in Onslow Bay, North Carolina

ALLYN B. POWELL
ROGER E. ROBBINS

*Beaufort Laboratory, Southeast Fisheries Science Center*
*National Marine Fisheries Service, NOAA*
*Beaufort, North Carolina 28516*

**ABSTRACT**

The abundance and distribution of ichthyoplankton adjacent to live-bottom habitats (rock outcroppings containing rich, sessile invertebrate communities and many species of tropical and subtropical fishes) in open-shelf waters (< 55-m isobath) in Onslow Bay, North Carolina, were investigated. Larvae of reef-associated genera, especially the economically important subtropical and tropical members of the families Haemulidae (*Haemulon*), Lutjanidae (*Lutjanus* and *Rhomboplites*), Serranidae (*Mycteroperca* and *Epinephelus*), and Sparidae (*Calamus* and *Pagrus*) were targeted.

Larvae representing 40 families were collected in neuston tows. Commonly collected reef-associated families were Balistidae, Blenniidae (dominated by the reef-associated *Parablennius marmoreus*), Mullidae, and Gobiidae. Larvae representing 70 families were collected in subsurface tows. Reef-associated families commonly collected included Apogonidae, Balistidae, Gobiidae, Haemulidae, Lutjanidae, Scaridae, and Serranidae. Larval *Haemulon* sp(p)., *Lutjanus* sp(p)., and *Rhomboplites aurorubens* were commonly collected and thus it is likely that these taxa spawn in Onslow Bay and recruit to live-bottom sites within the area. Other families of fishes commonly collected but generally not considered reef-associated included Bothidae, Callionymidae, Carangidae, Clupeidae, Engraulidae, and Ophidiidae.

Estuarine-dependent species (e.g. the clupeid *Brevoortia tyrannus* and the sciaenids *Leiostomus xanthurus* and *Micropogonias undulatus*) were an important component of the ichthyoplankton during late fall and winter. The frequent occurrence of larvae from oceanic species (e.g. gonostomatids and myctophids) indicated that Gulf Stream waters had intruded onto the shelf, transporting these larvae to open-shelf waters off North Carolina.

## Introduction

Small areas of rock outcroppings occur on the continental shelf off the southeastern United States. These patchy rock outcroppings, known also as hard-bottom or live-bottom habitats, contain rich, sessile invertebrate communities and support many species of subtropical and tropical fishes (Struhsaker, 1969; Miller and Richards, 1980). The commercial and recreational importance of many of the fish species associated with live-bottom habitat (Struhsaker, 1969) has stimulated a number of studies of the fish community structure associated with these habitats (Huntsman, 1976; Powles and Barans, 1980; Grimes et al., 1982; Wenner, 1983; Barans and Henry, 1984; Chester et al., 1984; Sedberry and Van Dolah, 1984; Parker, 1990). However, virtually nothing is known about the larval stages of these fishes and their recruitment to live-bottom habitats.

Most fish species associated with live-bottom habitats remain at the larval stage in the plankton for weeks or even months (Sale, 1980). Some larvae undergo extensive transport, whereas others may spend their entire life in close proximity to their natal reef (Munro and Williams, 1985; Kingsford and Choat, 1989). Both physical factors (e.g. currents, Ekman transport, eddies) and life history traits (including behavioral traits) play a role in reef fish recruitment. An understanding of the source of recruits is necessary to manage reef fish populations effectively.

This study describes the abundance and distribution of larvae of reef fish taxa to provide a basic framework for future recruitment studies. A review of reef fish species that occur in waters off North Carolina, along with spawning information, is also included. We also describe the abundance and distribution of commonly collected larvae of taxa that generally are not associated with live-bottom habitats but co-occur with larval reef fish species.

## Materials and Methods

### Collection of Material

The National Oceanic and Atmospheric Administration's (NOAA) vessel *Onslow Bay*, a 17-m wooden sportfisherman, was used on most cruises. Three cruises during early fall and early winter were conducted with NOAA vessels *Chapman*, *Oregon II*, and *Albatross*, at 36.5, 52, and 55 m, respectively. Three hard-bottom sites (station 1: 34°35.9'N, 76°36.6'W; station 2: 34°26.5'N, 76°33.7'W; and station 3: 34°14.6'N, 76°35.5'W) were sampled from August 1990 through May 1993 (Fig. 1; Table 1). An additional site (station 4: 34°08.7'N, 76°34.2'W) was added in June 1992 but was infrequently sampled because of weather conditions (Table 1). All ichthyoplankton samples were collected with either a 333-mm mesh net mounted on a 60-cm diameter bongo sampler (August 1990 to May 1992), a l-m$^2$ Tucker trawl with a single net (May 1992 to May 1993), or a multiple open-closing net and environmental sensing systems (MOCNESS; February 1992) (Wiebe et al. 1985). Nets were fished from a boom projecting from the side to avoid disturbance from the vessel's wake. Sampling on the NOAA vessel *Onslow Bay* was conducted solely during the day. Sampling aboard the NOAA vessel *Oregon II* (cruise 10), *Chapman* (cruise 19), and *Albatross* (cruise 20) was conducted day and night depending upon when the vessel reached the station. The gear employed in this study was anticipated to catch ichthyoplankton in densities and size distributions similar to those observed by Shima and Bailey (1994), who used the same gear.

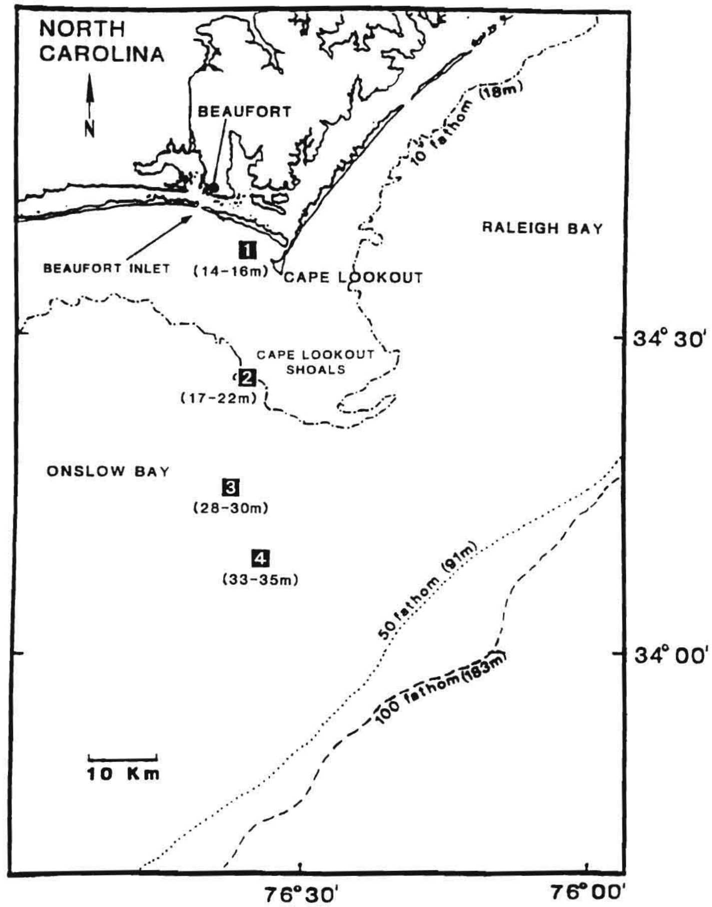


**Figure 1**
Location of sampling stations 1–4 and, in parentheses, water depth of stations at live-bottom sites in Onslow Bay, off North Carolina. Cape Hatteras and Cape Fear are located northeast and southwest of Cape Lookout, respectively.

The following tow types were employed: 1) surface tow (station 1)—net submerged 1 m below surface and towed for 5 min ; 2) bottom tow (all stations)—net rapidly deployed to within 3 m of bottom (as determined by the amount of wire released out and the wire angle), left at this depth for 30 sec, towed for 5 min, and brought rapidly to the surface, 3) bounced oblique tow (stations 2–4)—nets rapidly deployed to depth, left at desired depth for 30 sec, retrieved at a rate of 20 m per min until the net broke the surface, and the process repeated one more time, 4) stepped oblique tows (MOCNESS net at station 3)—net deployed to 25 m depth, samples taken in five depth strata for approximately 2–3 min per stratum, and 5) neuston tow (all stations)—nets fished partially out of the water for 5-min duration. With the exception of the neuston tows, nets were towed to maintain a 45° wire angle (speed approximately 1.5 knots). Surface, bottom, bounced oblique, and stepped oblique tows are defined as subsurface tows to differentiate them from neuston tows. Larvae were preserved in 95% ethyl alcohol. Surface temperatures were recorded (Append. Table 1), and periodically, 14 Nov 1994 through 17 Aug 1994, bottom temperature data were obtained from a data logger placed at station 3.

Taxa were classified by geographic range and habitat of adults to allow comparisons between habitat groups similar to those reported by Powell and Robbins (1994): 1) estuarine dependent—species that spawn in coastal and shelf waters but reside in estuaries during their juvenile stage; 2) coastal—species that commonly in-

**Table 1**
List of stations sampled by tow type, gear, date, cruise, and season. Bongo = 60-cm paired bongo net, 0.333-mm mesh; MOCNESS = 1-$m^2$ multiple opening-closing net and environmental sensing system, 0.333-mm mesh; Tucker = 1-$m^2$ Tucker trawl = 0.333-mm mesh. B = bottom tow; N = neuston tow; S = surface tow; BO = bounced oblique tow; SO = step-oblique tow.

| | | | | Station | | | |
|---|---|---|---|---|---|---|---|
| Season | Cruise number | Date | Gear | 1 | 2 | 3 | 4 |
| Winter | 10 | 4–11 Feb 1991 | Bongo | B,N | B,N | B,N | |
| | 20 | 1 Feb 1992 | Mocness | | | SO | |
| Spring | 11 | 21 May 1991 | Bongo | B,S,N | | | |
| | 12 | 23 May 1991 | Bongo | | B,N | B,BO,N | |
| | 21 | 13 May 1992 | Tucker | | B,N | B,N | |
| | 24 | 1 May 1993 | Tucker | B,N | B,N | | |
| | 25 | 3 May 1993 | Tucker | | | B,N | B,N |
| Summer | 1 | 16 Aug 1990 | Bongo | S,N | BO | BO,N | |
| | 2 | 29 Aug 1990 | Bongo | | | B,BO,N | |
| | 13 | 4 Jun 1991 | Bongo | B,N | B,N | | |
| | 14 | 11 Jun 1991 | Bongo | | | B,BO,N | |
| | 15 | 11 Jul 1991 | Bongo | | B,N | B,BO,N | |
| | 16 | 12 Jul 1991 | Bongo | N | | | |
| | 17 | 27 Aug 1991 | Bongo | B,N | B,BO,N | B,BO,N | |
| | 22 | 1 Jun 1992 | Tucker | | B,N | B,N | B,N |
| Fall | 3 | 11 Sep 1990 | Bongo | | N | B,BO,N | |
| | 4 | 19 Sep 1990 | Bongo | B | | | |
| | 5 | 25 Sep 1990 | Bongo | | B,BO | B | |
| | 6 | 3 Oct 1990 | Bongo | | B,N | B,N | |
| | 7 | 1 Nov 1990 | Bongo | | B,N | B,N | |
| | 8 | 5 Nov 1990 | Bongo | B[1] | | | |
| | 9 | 27 Nov 1990 | Bongo | B,N | B,N | B,N | |
| | 18 | 18 Sep 1991 | Bongo | B,S,N | B,BO,N | B,BO,N | |
| | 19 | 8–13 Oct 1991 | Bongo | B,S,N | B,N | B,BO,N | |
| | 23 | 26 Oct 1992 | Tucker | | B,N | B,N | B,N |

[1] Net damaged.

habit depths to 18 m; 3) open shelf—species that commonly inhabit depths of 18–55 m; 4) reef—species that commonly inhabit live-bottom habitats on the open shelf; 5) outer shelf—species that commonly inhabit depths of 55–185 m, a narrow, steep habitat off North Carolina; 6) oceanic—epipelagic, mesopelagic, and bathypelagic species that are found in waters over the continental slope (>185 m); and 7) other—species not classified as outer-shelf or oceanic and that are not known to spawn in coastal or open-shelf waters off North Carolina. Scientific names follow Robins et al. (1991).

Arithmetic means were used to average the number of larvae per 100 $m^3$ when more than one subsurface tow was processed for a station and also to average the number of larvae per 5-min tow when more than one neuston tow was processed. This resulted in a total of 48 observations for subsurface tows and 45 observations for neuston tows. Data (numbers/100$m^3$ or numbers/5-min tow) when reported on a monthly basis were averages (arithmetic means) over years.

## Larval Fish Identification

Identification of larvae to species resulted in tentative identifications of certain taxa. Within the family Ophidiidae, *Ophidion robinsi* and *O. grayi* can be separated by meristic characters but have similar pigmentation (Gordon et al., 1984; Fahay, 1992; this study). Because many of these larvae have not fully developed meristic characters, we treated them as one category: "*O. robins* or *grayi*." We initially combined *O. beani* and *O. holbrooki*, two species that share broadly overlapping meristic counts (Gordon et al., 1984), into one type. Later we discovered one specimen had meristic characters (anal rays=106, dorsal rays=125) unique to *O. holbrooki*. Both these species have different pigment patterns. *Ophidion beani* was similar to *Ophidion* type 1 of Gordon et al. (1984), except pigment was contained below the lateral line and was continuous over the gut to head. *Ophidion holbrooki* had characteristic posterior caudal pigmentation. There were five to six melanophores above and four melanophores below the notochord. There was a series of melanophores along the base of anal-fin pterygiophores and approximately four melanophores at the distal edge of the anal-fin pterygiophores. No dorsal midline pigment was observed.

Within the family Bothidae, not all species of the genera *Etropus* and *Citharichthys* have been described in detail (i.e. *E. rimosus*, *E. cyclosquamus*, and *C. microps*) (Tucker, 1982; Leslie and Stewart, 1986); therefore identification of larvae of these genera to species should be considered tentative. We assigned *Etropus* larvae to two types—*Etropus* type A, which resembles *E. crossotus* in the presence of elongated dorsal rays (Tucker, 1982), and *Etropus* type B, which resembles *E. microstomus* in the absence of elongated dorsal rays (Richardson and Joseph, 1973).

Within the family Carangidae, there were some differences in the pigment pattern of *Decapterus punctatus* described in the literature (Laroche et al., 1984) and that observed by us. Laroche et al. (1984) reported that *Decapterus* spp. lack embedded melanophores over the notochord, embedded melanophores over the dorsal aorta, and scattered ventrolateral melanophores. We observed this pigment on several *Decapterus* specimens, and counts of meristic characters on cleared and stained specimens matched those described for *Decapterus punctatus* (Fahay, 1983). Numerous cleared and stained *Decapterus* sp(p). larvae had 25 vertebrae. On this basis (Fahay, 1983), we assigned all our *Decapterus* spp. to *Decapterus punctatus*.

We collected three Serraninae larvae similar in size and shape and in pigmentation. One of these had pigment identical to that of *Centropristis striata* (Kendall, 1972, 1979; Fahay, 1983). One other species of *Centropristis* (*C. ocyurus*) commonly occurs in waters off North Carolina (Grimes et al., 1982), but larvae of this species have not been described; therefore the *Centropristis striata* type was considered *Centropristis* sp(p). The second type of Serraninae larvae resembled *Centropristis striata* (Fahay, 1983), but a melanophore was absent on the ventral side of the gut. We named this Serraninae type A and suspect it might be *C. ocyurus*. The third type of Serraninae larvae lacked ventral melanophores on the gut and pelvic-fin insertions and had 12 dorsal rays (vs. 11 dorsal rays in *Centropristis*). These larvae were considered to be *Diplectrum formosum*, although *D. bivittatum*, which ranges from Bermuda, Florida, and the northern Gulf of Mexico to Brazil (Robins and Ray, 1986), may have occurred in our samples.

Within the family Gobiidae, older larvae of *Ioglossus calliurus* were readily identified by counts of meristic characters, especially the specific dorsal pterygiopohore formula (Birdsong et al., 1988). A specific pigment pattern allowed us to identify smaller larvae. Four other types were identified. Gobiidae type A had distinct pigmentation which included streaks of ventrolateral melanophores along the postanal myosepta. Two large larvae were cleared and stained for counts of meristic characters. Both had 10 precaudal and 16 caudal vertebrae; a 3-12210 dorsal pterygiophore pattern (Birdsong et al., 1988); and six first dorsal-fin spines. One larva had 12 second dorsal-fin rays and 13 anal-fin rays; the other 11 second dorsal-fin rays and 12 anal-fin rays. Gobiidae type B had less distinct pigmentation, which included ventral postanal melanophores and the last melanophore generally extending upward. Six type B larvae were cleared and stained for counts of meristic characters. All had vertebral counts, dorsal pterygiophore patterns, and first dorsal-fin spine counts indentical to type A. Dorsal-fin ray and anal-fin ray counts were 11 and 12, respectively ($n$=2); 12 and 12, respectively ($n$=2); and 12 and 13, respectively ($n$=2). Gobiidae type C had distinct pigmentation that included photophore-like ventral postanal melanophores. Counts of meristic characters were as follows: dorsal fin = VI,10; anal fin = 9; pectoral fin = 16; precaudal + caudal vertebrae = 10 + 16; and dorsal pterygiophore pattern = 3-12210. Gobiidae type D was heavily pigmented and included dorsal and ventral melanophores, imbedded midlateral melanophores, and melanophores at the lower jaw angle, and tip of snout.

Within the family Blenniidae, we tentatively identified *Parablennius marmoreus* on the basis of counts of meristic characters and the absence of pigment on the pectoral fins.

## Results and Discussion

### Abundance and Diversity of Families

Representatives of 70 families were collected in subsurface tows at four live-bottom sites in Onslow Bay, NC. Clupeiformes (engraulids and clupeids) were the most numerous taxon collected (Table 2). Engraulids ranked first in abundance but occurred infrequently, reflecting the limited range of habitats this coastal species occupies in Onslow Bay. Seven families of species associated with live-bottom sites were considered abundant. Labrids were the most abundant reef fish taxon collected, but occurred infrequently. Gobiids were abundant and frequently collected. Serranids and haemulids were moderately abundant; serranids were the second most frequently occurring reef fish taxon, reflecting the great diversity of taxa within this family occurring in Onslow Bay (Schwartz, 1989).

Apogonids, lutjanids, and scarids were the least abundant of the seven families and were infrequently collected. Larvae from four families of demersal and benthic species ranking in abundance among the top

**Table 2**

Percent frequency of occurrence ($n$=48 observations) and abundance (mean numbers/100m$^3$ summed over all stations and cruises; $n$=48 observations) of commonly collected larvae (≥10 larvae) at the family level collected by subsurface tows from live-bottom sites in Onslow Bay, North Carolina.

| Family | Abundance (no. of fish) | Frequency of occurrence (%) | Family | Abundance (no. of fish) | Frequency of occurrence (%) |
|---|---|---|---|---|---|
| Engraulidae | 2,789 | 40 | Sparidae | 90 | 12 |
| Clupeidae | 949 | 48 | Tetraodontidae | 69 | 44 |
| Labridae | 848 | 38 | Stromateidae | 56 | 23 |
| Bothidae | 804 | 88 | Scombridae | 47 | 33 |
| Gobiidae | 789 | 65 | Scorpaenidae | 46 | 52 |
| Carangidae | 487 | 67 | Scaridae | 45 | 25 |
| Ophidiidae | 446 | 80 | Cynoglossidae | 27 | 42 |
| Sciaenidae | 427 | 35 | Apogonidae | 26 | 23 |
| Callionymidae | 361 | 56 | Blenniidae | 22 | 21 |
| Serranidae | 175 | 50 | Ophichthidae | 21 | 44 |
| Synodontidae | 142 | 62 | Gadidae | 18 | 10 |
| Triglidae | 118 | 52 | Syngnathidae | 16 | 31 |
| Balistidae | 115 | 54 | Priacanthidae | 10 | 21 |
| Haemulidae | 100 | 21 | | | |
| Lutjanidae | 91 | 35 | | | |

**Table 3**

Percent frequency of occurrence ($n$=45 observations) and abundance (mean numbers of larvae/5 min tow summed over all stations and cruises; $n$=45 observations) of commonly collected larvae (≥10 larvae) at the family level collected by neuston tows in Onslow Bay, North Carolina.

| Family | Abundance (no. of fish) | Frequency of occurrence (%) | Family | Abundance (no. of fish) | Frequency of occurrence (%) |
|---|---|---|---|---|---|
| Balistidae | 170 | 53 | Bothidae | 22 | 29 |
| Exocoetidae | 103 | 40 | Sciaenidae | 20 | 9 |
| Blenniidae | 77 | 18 | Engraulidae | 17 | 13 |
| Carangidae | 75 | 33 | Gobiidae | 14 | 16 |
| Gadidae | 54 | 16 | Mugilidae | 14 | 11 |
| Tetraodontidae | 50 | 31 | Stromateidae | 14 | 11 |
| Clupeidae | 44 | 20 | Ophidiidae | 12 | 11 |
| Mullidae | 30 | 20 | Callionymidae | 10 | 7 |
| Sparidae | 24 | 11 | | | |

10 were the bothids, callionymids, ophidiids, and sciaenids. Bothids were the most frequently collected family. Carangids, which are composed of mainly pelagic species, were also a dominant component of the ichthyoplankton (Table 2).

Representatives of 40 families were collected in neuston tows, 17 with mean densities ≥10 larvae/5-min tow (Table 3). Neuston tows were estimated to sample approximately 70 m$^3$ of water which approximated the minimum volume sampled in subsurface tows. Based on this approximation, the number of larvae representing the families Exocoetidae, Mullidae, and Mugillidae were collected an order of magnitude more in the neuston tows than in subsurface tows. The families Balistidae, Blenniidae, and Gadidae also were estimated to be more abundant in neuston tows, but numbers were of the same magnitude as those collected in subsurface tows (Table 2, 3). The balistids were the most frequently collected family followed by the exocoetids. Blenniids, mugillids, and mullids were infrequently collected. (Table 3).

## Reef Fish Larvae

Reef fish larvae collected in subsurface tows were most abundant during spring, summer, and early fall (Append. Table 2). Collections at station 3 contained the largest number of reef fish taxa, and larvae were rarely collected at the live-bottom site in coastal waters (station 1). A taxonomic account (alphabetical order) of the reef fish larvae collected follows:

**Acanthuridae (Surgeonfishes)**—*Acanthurus* larvae were collected only in May and only at station 2 (Append. Table 2). Three species of *Acanthurus, A. bahianus, A. coeruleus,* and *A. chirugus,* have only infrequently been observed by divers at station 3 (Parker, 1990), and their absence in other reef fish monitoring studies in the South Atlantic Bight (Cape Hatteras, NC, to Cape Canaveral, FL) (Powles and Barans, 1980; Wenner, 1983; Sedberry and Van Dolah, 1984) suggests that they may be rare in South Atlantic Bight (SAB) open-shelf live-bottom habitats.

**Apogonidae (Cardinalfishes)**—Apogonid larvae (all unidentified) were collected during most months except February and August. Larvae were mainly collected at station 3 and never collected in coastal waters (Append. Table 2). The largest collection (13.5 larvae/100 $m^3$) was obtained during May 1991 at station 3; apogonid larvae were not collected during any other May cruise (Fig. 2).

Three species of apogonids have been reported to occur in North Carolina, *Apogon pseudomaculatus, Astrapagon alutus,* and *Phaeopteryx pigmentaria* (Schwartz, 1989). *Apogon pseudomaculatus* is the most commonly collected apogonid in reef fish monitoring surveys in North and South Carolina waters (Powles and Barans, 1980; Grimes et al., 1982; Wenner, 1983; Sedberry and Van Dolah, 1984). Although *Apogon pseudomaculatus* is the only apogonid reported by divers in North Carolina waters (Clavijo et al., 1989; Parker, 1990), recent collections of adults (Ross[1]) in Onslow Bay suggest that *P. pigmentaria* may commonly occur. Additional apogonids

[1] Ross, S. W. 1995. Center for Marine Research, University of North Carolina at Wilmington, 7205 Wrightsville Ave., Wilmington, NC 28403. Unpubl. data.

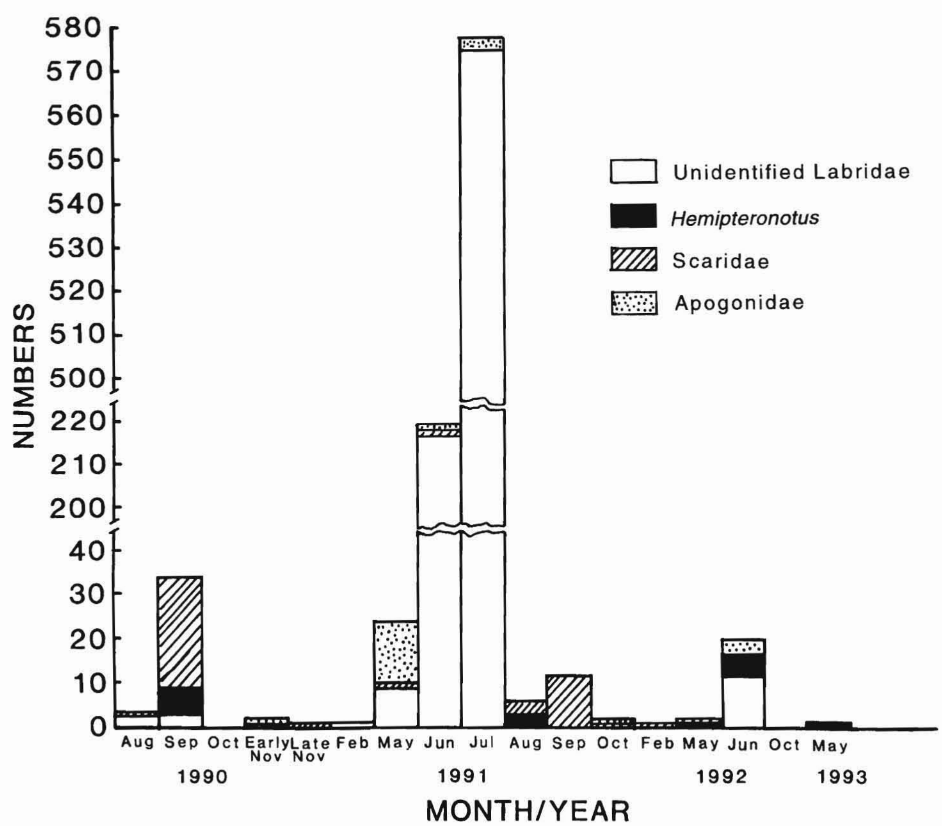


**Figure 2**

Total number (numbers/100$m^3$ summed over all stations sampled) of reef-associated apogonid, labrid, and scarid larvae collected by month and year in subsurface tows in Onslow Bay, North Carolina.

observed in those collections (Ross[1]) also include *Apogon affinis*, *A. maculatus*, *A. aurolineatus*, and *A. aluterus*. Within these Onslow Bay collections, a gravid *A. aurolineatus* female and *A. pseudomaculatus* with eggs in its buccal cavity were observed, providing evidence that these two species spawn in Onslow Bay.

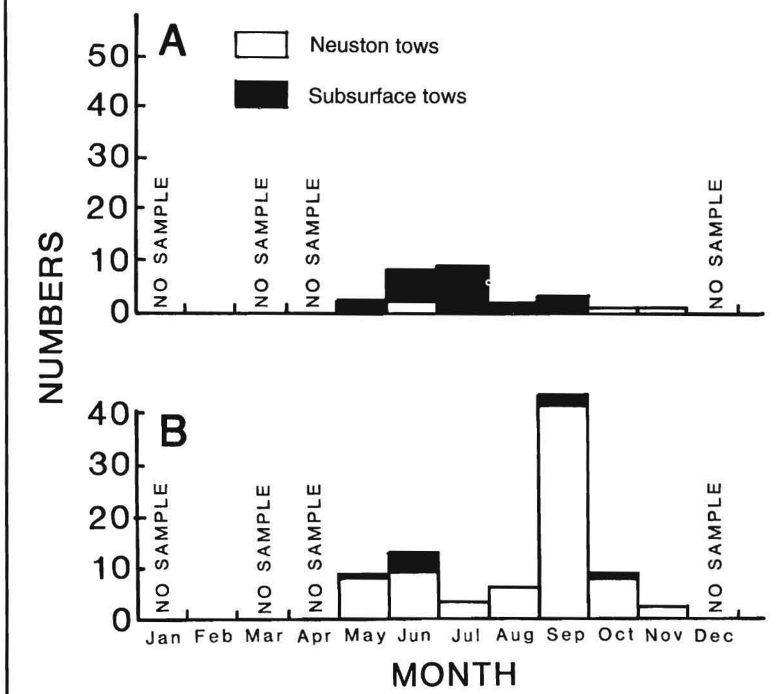


**Figure 3**
Total number (numbers/100m$^3$, and numbers/5-min tow summed over all stations for subsurface and neuston tows, respectively) of reef-associated (A) unidentified balistid larvae; and (B) *Monacanthus hispidus* larvae collected in neuston and subsurface tows by month (years combined) in Onslow Bay, North Carolina.

**Balistidae (Leatherjackets)**—All balistid species that were reported to occur in waters off North Carolina (Robins and Ray, 1986; Schwartz, 1989) were considered reef-associated species. Balistid larvae ranked first in abundance in neuston collections, thirteenth in abundance in subsurface collections (Table 2, 3). *Monacanthus hispidus* was the most commonly collected balistid. Based upon the abundance of adults in South Atlantic Bight waters (Cape Hatteras, NC, to Cape Canaveral, FL) (Powles and Barans, 1980; Wenner, 1983) and the extreme abundance of juveniles in pelagic *Sargassum* (Dooley, 1972; Settle, 1993), the majority of our unidentified balistids and our *Monacanthus* sp(p). were most likely *M. hispidus*. The majority of unidentified balistids and *Monacanthus* sp(p)., which had undeveloped meristic characters, were collected in subsurface tows, while positively identified *M. hispidus*, which had developed meristic characters, were collected in neuston tows (Fig. 3). The smaller larvae were collected from May through September (Fig. 3A), coinciding with the spawning season of *M. hispidus* in Onslow Bay (Hildebrand and Cable, 1930). *Monacanthus ciliatus*, the only other *Monacanthus* identified, was rarely collected (Append. Table 2, 3). It was taken during late summer through fall. This species has been reported to spawn throughout the year in waters off Florida (Dooley, 1972). *Aluterus* sp(p). were collected from May through October, but in small numbers (Append. Table 2, 3).

*Balistes capriscus* is the only balistid of direct economic importance that occurs in waters off North Carolina and was collected, rarely, in September (Append. Table 3). However, this species was the second most abundant juvenile balistid collected in pelagic *Sargassum* in waters off North Carolina (Settle, 1993). Spawning in waters off Florida is estimated to occur from July through October (Dooley, 1972), and in waters off North Carolina during spring and summer (Manooch, 1984).

**Blenniidae (Combtooth Blennies)**—*Parablennius marmoreus* was collected almost exclusively in neuston tows, June and October (Append. Table 2, 3). We identified numerous small specimens on the basis of lack of pigment on pectoral fins, a feature verified from older material. This is the most commonly observed blenny on live-bottom habitats in Onslow Bay (Clavijo et al., 1989; Parker, 1990).

**Carangidae (Jacks)**—Following Manooch (1984), we consider the genus *Seriola* as reef fish, and treat other carangids elsewhere. We were unable to identify our *Seriola* to species. *Seriola* sp(p). were collected only in neuston tows, June through September, at stations 2–4 (Append. Table 3). Powles and Stender (1976) collected a large number (212) of larval *Seriola* sp(p). in neuston tows within the South Atlantic Bight (SAB) during February and March. *Seriola rivoliana* and *S. dumerili* were the most commonly collected *Seriola* spp. in pelagic *Sargassum* in waters off North Carolina (Settle, 1993). *Seriola dumerili* has been reported to spawn in SAB waters during fall, winter, and spring, *S. rivoliana* in summer and fall (Fahay, 1975).

**Chaetodontidae (Butterflyfishes)**—Chaetodontid larvae were occasionally collected in subsurface tows during summer months at station 3 (Append. Table 2). Five chaetodont species (*Chaetodon aya, C. capistratus, C. ocellatus, C. sedentarius,* and *C. striatus*) have been reported to occur in waters off North Carolina (Schwartz, 1989). *Chaetodon ocellatus* and *C. sedentarius* appear to be the most common species in North and South Carolina waters on the basis of reef fish surveys (Powles and Barans, 1980; Grimes et al., 1982; Wenner, 1983; Clavijo et al., 1989; Parker, 1990).

**Clinidae (Clinids)**—Unidentified clinid larvae were collected in subsurface and neuston tows from August through November at stations 1–3 (Append. Tables 2, 3). *Starksia ocellata* is the only clinid reported to occur in waters off the Carolinas (Robins and Ray, 1986; Schwartz, 1989).

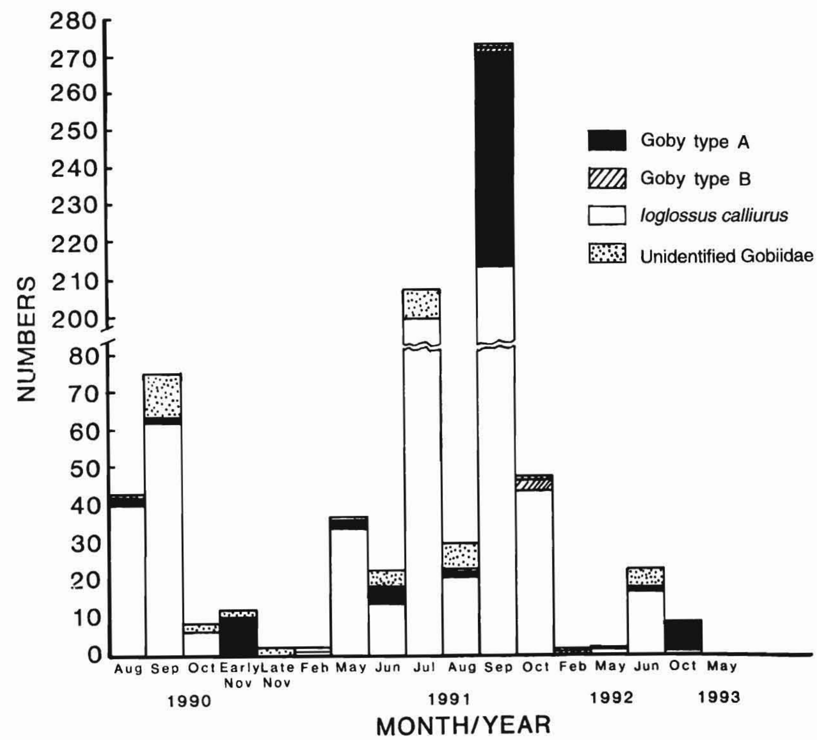


**Figure 4**
Total number (numbers/100m$^3$ summed over all stations sampled) of gobiid larvae (selected taxa) collected by month and year in subsurface tows in Onslow Bay, North Carolina.

**Congridae (Conger Eels)**—Congrid leptocephali were collected in subsurface tows in September, October, and February (Append. Table 2). Three reef-associated congrid species occur in waters off the Carolinas: *Ariosoma balearicum, Conger oceanicus,* and *Paraconger caudilimbatus* (Powles and Barans, 1980; Grimes et al., 1982; Wenner, 1983; Schwartz, 1989; Parker, 1990). *Ariosoma balearicum* larvae are the most common leptocephali in the western North Atlantic (Smith, 1989). *Ariosoma balearicum* populations from North Carolina waters may also spawn in the Sargasso Sea (McCleave and Miller, 1994). *Conger oceanicus* spawns in the Sargasso Sea, and leptocephali must cross the Gulf Stream to colonize juvenile habitats on the continental shelf (McCleave and Miller, 1994). *Paraconger caudilimbatus,* although reported from waters off North Carolina (Schwartz, 1989), is mainly distributed in the Gulf of Mexico, off Florida, and in the Caribbean (Smith, 1989).

**Gobiidae (Gobies)**—Gobiid larvae were usually collected in subsurface tows (Append. Table 2). The most abundant gobiid, *Ioglossus calliurus,* was collected May through October, suggesting a protracted spawning period (Fig. 4). Although this gobiid was taken at all live-bottom sites, it was more consistently captured at station 3. The largest collections of *Ioglossus* were made during July and September at station 3. The second most abundant gobiid, Gobiidae type A, was collected at all live-bottom sites in open-shelf waters during spring, summer, and fall, but more consistently at station 3 (Fig. 4). The largest collection of Gobiidae type A (54.5 larvae/100 m$^3$), however, was taken during cruise 18 (Sep 1991) at station 2. Larvae were absent or collected in small numbers during three other September cruises (cruises 3, 4, and 5).

We collected and positively identified only one of nine gobiid species that are known to occur at live-bottom sites in waters off North Carolina (Rohde and Ross, 1987). Eight species not identified were *Coryphopterus glaucofraenum, C. punctipectophorus, Evermannichthys spongicola, Gnatholepis thompsoni, Gobiosoma xanthiprora, Lythrypnus phorellus, L. spilus,* and *Psilotris hipoliti.* There are two offshore species that are not associated with reefs, but with sand or shell (or both) bottoms, *Gobionellus saepepallens* and *Microgobius carri. Gobionellus saepepallens* was not positively identified, but could be type A or B. *Microgobius carri* larvae were collected on one occasion at station 3 during the fall.

**Haemulidae (Grunts)**—*Haemulon plumieri* and *H. aurolineatum* occur on live-bottom habitats in Onslow

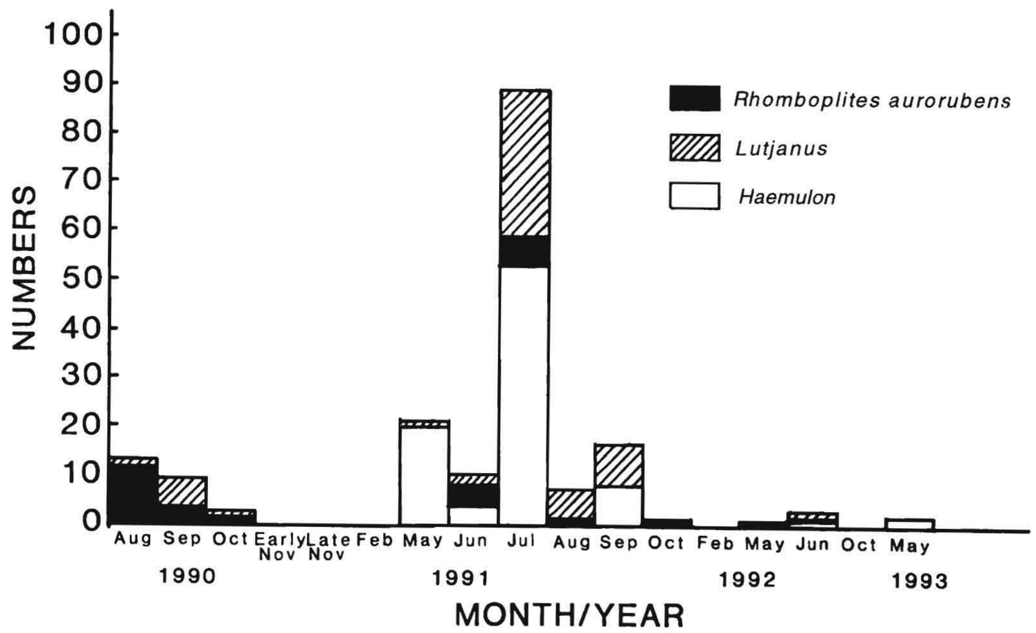


**Figure 5**

Total number (numbers/100m$^3$ summed over all stations sampled) of reef-associated haemulid (selected taxa), and lutjanid (selected taxa) larvae collected by month and year in subsurface tows in Onslow Bay, NC.

Bay (Chester et al., 1984; Parker, 1990). Larvae of *H. plumieri* have been described (Saksena and Richards, 1975), but those of *H. aurolineatum* have not. We, therefore, denote all haemulids that resemble *H. plumieri* as *Haemulon* species.

Larval *Haemulon* sp(p). were collected May through July, indicating spawning during this period, and were more abundant at station 2 (Fig. 5; Append. Table 2). The largest collections of *Haemulon* sp(p). were made at station 2, cruise 12 (May 1991; 20 larvae/100 m$^3$) and cruise 15 (July 1991; 53 larvae/100 m$^3$).

*Haemulon plumieri* and *H. aurolineatum* are abundant in waters off North Carolina (Parker, 1990). Spawning of *H. aurolineatum* in the SAB appears to occur in April and May (Manooch and Barans, 1982), *H. plumieri* from May through August, with a peak in June and July (Manooch et al.[2]). Based upon these spawning times, our large collection in July (Fig. 5) could be *H. plumieri*.

**Holocentridae (Squirrelfishes)**—Only one holocentrid (*Holocentrus* sp.) was collected (June at station 3) (Append. Table 2). Six species of holocentrid have been reported to occur in waters off North Carolina (Schwartz, 1989), but *Holocentrus adscensionis* appears to be the dominant holocentrid in SAB waters. This species appears to be more common in outer shelf habitats (Grimes et al., 1982; Wenner, 1983; Parker and Ross, 1986), hence their rarity in our collections. Although spawning of *H. adscensionis* in May in waters off North Carolina has been documented (Manooch, 1984), it is most likely protracted (Munro et al., 1973; Tyler et al., 1993).

**Labridae (Wrasses)**—Labrids were collected in subsurface tows during all months, except October and November, and were most abundant at stations 2 and 3 (Append. Table 2). Despite their abundance in subsurface tows, they were rarely caught in neuston tows (Append. Table 3). Two large collections of unidentified labrids were taken during cruise 13 (Jun), station 2 (202 larvae/100 m$^3$) and during cruise 15 (Jul), station 2 (567 larvae/100 m$^3$) (Append. Table 2; Fig. 2). *Hemipteronotus* sp(p). larvae were collected from spring to fall, but not in July (Append. Table 2; Fig. 2). Abundance of this labrid, and other labrid species, may be misleading as a large percentage of the larvae were unidentified.

All members of the Labridae occurring off North Carolina are reef-associated species (Schwartz, 1989). Although only one labrid was identified below the familial level, *Hemipteronotus* sp(p)., and only *H. novacula* is known to occur in waters off North Carolina (Schwartz,

[2] Manooch, C. S., R. H. Matheson, and D. L. Mason. 1983. Foods and reproductive cycle of white grunt, *Haemulon plumieri*, off North Carolina and South Carolina. Unpubl. manuscript.

1989), other subtropical *Hemipteronotus* sp(p). could occur. We believe, however, that our *Hemipteronotus* spp. collections were most likely *H. novacula.*

**Lutjanidae (Snappers)**—There are 14 species of lutjanids reported to occur in waters off North Carolina (Schwartz, 1989). It appears from recreational (Grimes et al., 1977; Dixon[3]) and commercial (Rohde and Francesconi[4]) landings, visual observations (Barans and Henry, 1984; Lindquist et al., 1989; Parker, 1990), and trawl and trap surveys (Powles and Barans, 1980; Wenner, 1983; Sedberry and Van Dolah, 1984) that four species commonly occur. They are in order of descending abundance: *Rhomboplites aurorubens, Lutjanus campechanus, L. vivanus,* and *L. buccanella.* Of these, only larval *R. aurorubens* and *L. campechanus* have been described (Laroche, 1977; Collins et al., 1980). We therefore refer to larvae resembling *L. campechanus* as *Lutjanus* species.

*Rhomboplites aurorubens* larvae were collected in subsurface tows from May through October, but the majority were collected from June through September (Append. Table 2; Fig. 5). Larvae were more frequently collected at station 3 ($n$=11 cruises) than at station 2 ($n$=4 cruises) and station 4 ($n$=1 cruise), but the largest collection (11.1 larvae/100 $m^3$) was obtained at station 2 during cruise 1 (Aug). This species appears to spawn on the open shelf in Onslow Bay.

The spatial and temporal distribution and abundance of *Lutjanus* sp(p). was similar to that observed for *R. aurorubens* (Append. Table 2). Larvae were collected (6 larvae/100 $m^3$) only at station 2 during one cruise (cruise 17, Aug). The largest collection (29.8 larvae/100 $m^3$) was obtained during cruise 15 (Jul) at station 3 (Append. Table 2; Fig. 5). Lutjanid larvae were never collected in neuston tows.

The reported spawning period for *R. aurorubens,* based upon visual observation of gonads, is in general agreement with our results. *Rhomboplites* is in spawning condition from April through September (Grimes and Huntsman, 1980). However, we collected only one larva in May.

The spawning periods of *L. campechanus* and *L. vivanus* overlap. *Lutjanus campechanus* has been reported to spawn in the South Atlantic Bight, May through September (Grimes et al., 1977; Grimes, 1987) and *L. vivanus,* June through August (Grimes et al., 1977). Spawning information for *L. buccanella* in the SAB is lacking and for other numerous lutjanids that occur in this area.

[3] Dixon, R. 1995. Beaufort Laboratory, National Marine Fisheries Service, NOAA, 101 Pivers Island Road, Beaufort, North Carolina 28516. Unpubl. data.

[4] Rohde, F. C., and J. J. Francesconi.1992. Reef fish and coastal pelagic fisheries assessment, Job 5. *In* Assessment of North Carolina Commercial finfisheries, 68 p. North Carolina Div. of Marine Fisheries. Completion rep. for Project 2-IJ-16.

**Malacanthidae (Tilefishes)**—Malacanthid larvae were collected only on one occasion (Append. Table 2). Five species of malacanthids occur off North Carolina, and two (*Caulolatilius microps* and *Lopholatilus chamaeleonticeps*) occur in numbers that make them of economic importance (Manooch, 1984; Rohde and Francesconi[4]). *Lopholatilus chamaeleonticeps* inhabits the continental slope (180–300 m) (Barans and Stender, 1993) and has a protracted spawning period, March to November, with a peak in May to September (Grimes et al., 1988). *Caulolatilus macrops* inhabits the outer continental shelf, shelf break, and upper slope (70–235 m) (Ross and Huntsman, 1982) and has a protracted spawning period, April through October, with peak activity off North Carolina in May–June and September–October (Ross and Merriner, 1983). Absence of larvae in our collections, as well as the distribution of adults, suggested that spawning occurred in waters seaward of the open-shelf.

**Mullidae (Goatfishes)**—Larval mullids were seldom collected in subsurface tows but were an important component of the ichthyoplankton taken in neuston tows (Table 2, 3). Mullids were collected at stations 2 or 3 in May (or both), June through August, and November (Appendix Table 3). The largest collection (15 larvae/5 min tow) was obtained from a neuston tow during cruise 15 (Jul 1991) at station 3 (Append. Table 3).

*Mullus auratus* appears to be the most common mullid in the SAB followed by *Pseudupeneus maculatus* and *Upeneus parvus* (Struhsaker, 1969; Fahay, 1975). *Mullus auratus* has been reported to spawn January into May, based upon the presence of small larvae (Caldwell, 1962; Fahay, 1975), but our largest collection of mullid larvae was taken in July.

**Muraenidae (Morays)**—Muraenid leptocephali were rarely collected (Append. Table 2). *Gymnothorax* sp. was the only muraenid identified below family level. This genus was collected in June and July at station 3. Unidentified muraenids were collected in October at stations 3 and 4. They were never collected in neuston tows.

*Gymnothorax moringa, G. saxicola, Muraena retifera,* and *M. robusta* are reported to occur in waters off North Carolina (Schwartz, 1989). *Muraena robusta* was the most common muraenid observed from submersibles off North Carolina by Parker and Ross, (1986), but leptocephali of *Muraena* have never been identified (Smith, 1989).

**Pomacanthidae (Angelfishes)**—Larval pomacanthids were infrequently collected (Append. Table 2) at station 3 in spring, early summer, and fall. *Holacanthus* was the only genus identified. Of the five species of pomacanthids that have been reported to occur in waters off North Carolina (Parker and Ross, 1986; Schwartz, 1989), *Holacanthus bermudensis* appears most commonly (Struhsaker, 1969; Parker and Ross, 1986; Parker, 1990). We are unaware of any information on the spawning of pomacanthids in the SAB.

**Pomacentridae (Damselfishes)**—Pomacentrid larvae were collected from late spring to mid-fall, stations 2–4 (Append. Table 2). Unidentified pomacentrid larvae were collected in May, June, September, and October. *Abudefduf saxatilis* and *Chromis* sp(p). were collected in June, and *Pomacentrus* sp(p). were collected in June and July.

Parker and Ross (1986) observed five species of pomacentrids from submersibles operating in waters off North Carolina. *Chromis enchrysurus* was commonly observed between the 52- and 98-m isobaths but was scarce in waters <34 m. *Chromis scotti* was also commonly observed, but in depths <50 m. Other pomacentrids reported by Parker and Ross were *C. insolatus*, *P. partitus*, and *P. planifrons*. Parker (1990) reported *C. scotti* as the most frequently occurring pomacentrid at our station 3. Parker also noted numerous, recently recruited juveniles at the end of May and June. *Chromis enchrysurus* was frequently observed and some recent recruits were observed from the end of May to mid-July. *Pomacentrus variabilis* and *P. partitus* were occasionally observed, whereas *C. cyanea*, *C. multilineata*, *C. insolatus*, *P. fuscus*, and *Microspathodon chrysurus* were rarely seen. Based on observations by Parker and Ross (1986), Clavijo et al. (1989), and Parker (1990) *C. enchrysurus* appears to be the most abundant pomacentrid in outer-shelf, live-bottom habitats, whereas *C. scotti* appears to be the most abundant pomacentrid in open-shelf, live bottom habitats. Based upon the presence of recently recruited juveniles (Parker, 1990) and the general planktonic duration (25–30 days) of pomacentrids (Wellington and Victor, 1989), *C. enchrysurus* appears to spawn in waters off North Carolina in May and June.

**Priacanthidae (Bigeyes)**—Larval priacanthids were collected May through September at stations 2–4, but in low numbers (Append. Table 2). *Pristigenys alta* was the only priacanthid identified to species, occurring in June and August.

All four species of western Atlantic priacanthids have been reported to occur in waters off North Carolina (Caldwell, 1962b; Schwartz, 1989). *Pristigenys alta* appears to be the most common priacanthid inhabiting live-bottom habitats on the open shelf off North Carolina, followed by *Priacanthus arenatus* and *Heteropriacanthus cruentatus*. *Cookeolus japonicus*, an offshore species, is rarely collected (Struhsaker, 1969; Powles and Barans, 1980; Grimes et al., 1982; Wenner, 1983; Barans and Henry, 1984; Sedberry and Van Dolah, 1984; Parker and Ross, 1986). Our collections of *P. alta* during summer and early fall are in concordance with spawning times (late June–mid September) reported by Caldwell (1962a).

**Scaridae (Parrotfishes)**—Scarid larvae were collected in all seasons at live-bottom sites in coastal and open-shelf waters (Append. Table 2). *Sparisoma* sp(p). larvae were collected at station 3 during late summer. Scarids were commonly collected in the early fall; during one September cruise at station 3 we collected them at densities of 23.1 larvae/100 $m^3$ (Fig. 2).

There are five species of scarids that have been reported to occur in waters off North Carolina (Schwartz, 1989): *Nicholsina usta*, *Scarus coeruleus*, *Scarus croicensis*, *Sparisoma radians*, and *Sparisoma rubripinne*. The two species of *Sparisoma* prefer shallow water seagrass habitats (Robins and Ray, 1986) and have not been observed at live-bottom habitats off North Carolina (Parker and Ross, 1986; Clavijo et al., 1989; Parker, 1990). Our identification of *Sparisoma* was based on pigmentation from a single illustration (Richards, 1990). *Sparisoma* and *Nicholsina* share similar meristic characters (i.e. precaudal and caudal vertebrae), and we are concerned that there could either be similarities in pigment amongst the two species, or confusion as to these species. *Nicholsina usta*, which may be the most common scarid off the Carolinas (Powles and Barans, 1980; Wenner, 1983; Ross[1]), occurs in more open bottom waters and is, therefore, rarely observed at live-bottom habitats (Parker and Ross, 1986; Parker, 1990).

On the basis of illustrations reported by Richards, (1990), we believe that the majority of our unidentified scarids were *Scarus* because the majority of scarids that were collected in September 1991 (Fig. 2) exhibited ventral and dorsal pigmentation.

**Serranidae (Sea Basses)**—*Centropristis* sp(p)., Serraninae type A, and *Diplectrum formosum* were the most commonly collected serranid larvae (Append. Table 2; Fig. 6). These larvae were most abundant at station 2, May through June, but were also collected in reduced numbers during fall. Spawning of these three taxa most likely peaks during spring and summer, with minimal spawning during the fall. *Diplectrum* larvae were also collected in February, suggesting a protracted spawning period for *D. formosum* or possibly an intrusion of *D. bivittatum* from southern waters. Few larvae of another Serraninae genus, *Serranus*, were collected during June, July, and September (Append. Table 2).

Larvae of the subfamily Epinephelinae were rarely collected, with the exception of *Rypticus* sp(p)., which was collected June through September at stations 2 and 3 (Append. Table 2; Fig. 6). The majority of *Rypticus* sp(p). were collected at station 2, the largest collection made during August 1990. *Mycteroperca* larvae were never

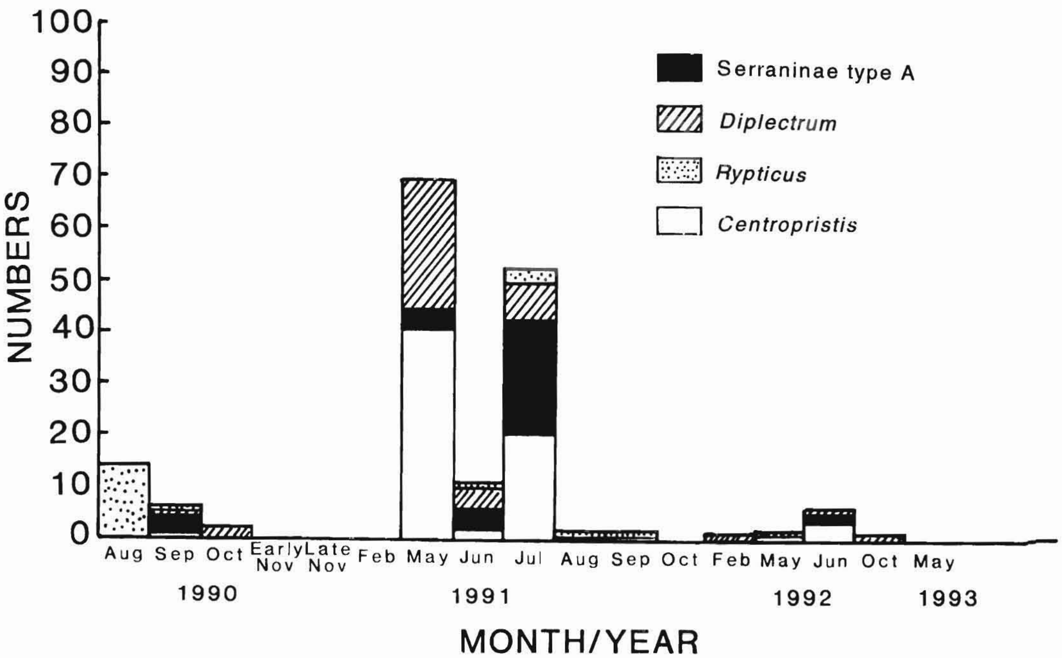


**Figure 6**
Total number (numbers/ 100m$^3$ summed over all stations sampled) of reef-associated serranid larvae (selected taxa) collected by month and year in sub-surface tows in Onslow Bay, NC.

collected. *Epinephelus* larvae were collected during late spring, summer, and early fall in low numbers. *Epinephelus cruenatus* was the only species that was positively identified (Johnson and Keener, 1984). This species occurred in September at station 3. One other epinepheline, *Liopropoma* sp(p)., was collected in June at station 4 (Append. Table 2).

*Centropristis striata,* one of three *Centropristis* reported to occur in waters off North Carolina (Schwartz, 1989), dominates commercial serranid landings in North Carolina (Rohde and Francesconi[4]) and is equally important in inshore recreational catches (Huntsman, 1976). *Centropristis ocyurus* is rarely landed commercially (Rohde and Francesconi[4]) but is more common in recreational catches, especially in deeper open-shelf waters (Huntsman, 1976; Dixon[3]). *Centropristis philadelphica* is rarely collected in open-shelf waters off the southeastern United States but has been collected in numbers comparable to those for *C. ocyurus* and *C. striata* in coastal waters from Cape Fear, NC, to Cape Canaveral, FL (Struhsaker, 1969; Schwartz and Porter, 1977; Wenner et al., 1979 a,b,c,d).

*Centropristis striata* spawns January through June in the SAB, with peak spawning March through May. Minor spawning occurs in September and October (Mercer, 1989). These spawning periods are in concordance with our collections of larval *Centropristis* sp(p). (Fig. 6). *Centropristis philadelphica* is reported to spawn from May to early June (Miller, 1959), but based on its adult distribution, it may not spawn in the SAB. *Centropristis ocyurus* is reported to spawn in spring (Manooch, 1984) and to be spawned out by early June (Miller, 1959). Our collections of Serraninae type A, which might be *C. ocyurus,* were taken in late spring, summer, and early fall (Fig. 6), suggesting either a more protracted spawning period for this species, or confusion by us as to the identity of Serraninae type A. Given the importance of *C. striata* (and to a lesser extent *C. ocyurus*) to commercial and recreational fisheries, there is a need for comparative studies to separate the three species of *Centropristis.*

Members of the subfamily Epinephelinae, notably the genera *Epinephelus* and *Mycteroperca,* are valuable to commercial and recreational fisheries (Huntsman, 1976; Manooch, 1984; Rohde and Francesconi[4]). *Mycteroperca microlepis,* one of five species of *Mycteroperca* occurring in waters off North Carolina, dominates commercial (Rhode and Francesconi[4]) and recreational (Dixon[3]) landings. This species is distributed along the entire Carolina open shelf, mainly at depths of 40–70 m (Chester et al., 1984) and has been commonly observed at our station 3 (Parker, 1990). *Mycteroperca phenax* is also important to commercial (Rohde and Francesconi[4]) and recreational (Dixon[3]) fisheries. It also occurs along the open shelf but is more restricted to the area around Cape Fear, NC, and along the South Carolina coast

(Chester et al., 1984). The other three species, ranked in order of decreasing abundance in commercial landings (Rohde and Francesconi[4]), are *M. interstitialis*, *M. venenosa*, and *M. bonaci*.

The absence of *Mycteroperca* larvae in our study and in a previous study in Onslow Bay (Powell and Robbins, 1994) is puzzling. *Mycteroperca microlepis* supposedly spawns in waters off North Carolina from winter to early spring, with a peak in late March and early April (Collins et al., 1987). *Mycteroperca phenax* supposedly spawns in waters off North Carolina, April through August, with a peak in May and June (Matheson et al., 1986). The absence of *Mycteroperca* larvae in our collections could be due to a lack of sampling during peak spawning periods for *M. microlepis*. If *M. microlepis* spawns in pulses similar to those for *Epinephelus striata* (Shenker et al., 1993), intensive sampling may be required to collect larvae. Additionally, the absence of *Mycteroperca* larvae in the study area, with respect to contributions by *M. phenax*, could be explained by spatial spawning habits. We sampled during the peak spawning period of *M. phenax*, but possibly not in areas where this species spawns. Based upon its distribution from commercial and recreational landings (Chester et al., 1984; Rohde and Francesconi[4]), spawning might occur south of Onslow Bay.

The rarity of *Epinephelus* larvae might be related to the distribution of this genus in Onslow Bay relative to our stations. There are seven species of *Epinephelus* that commonly occur in commercial and recreational landings (Huntsman, 1976; Chester et al., 1984; Rohde and Francesconi[4]). These are *E. niveatus*, the most important *Epinephelus* species (commercially and recreationally), *E. adscensionis*, *E. drummondhayi*, *E. flavolimbatus*, *E. guttatus*, *E. morio*, and *E. nigritus*. *Epinephelus niveatus*, *E. nigritus*, and *E. flavolimbatus* occur in outer-shelf habitats (>100 m) (Chester et al., 1984), a habitat not sampled in this study. *Epinephelus morio*, *E. adscensionis* and *E. guttatus* occur in open-shelf live-bottom habitats as well as in shallower waters of the outer-shelf habitat (40–70 m) but are more common south of Onslow Bay (Chester et al., 1984). *Epinephelus morio* was the only *Epinephelus* observed by Parker (1990) at our station 3. *Epinephelus drummondhayi* occurs at the edge of the open-shelf and outer-shelf habitats (50–100 m) and is more common south of Onslow Bay (Chester et al., 1984). Our small collections of *Epinephelus* larvae, then, may be attributed to inadequate sampling in deeper and more southern waters. Even if *Epinephelus* larvae could be effectively collected, the difficulty in identifying this group to species impedes early life history studies. For example, *E. morio*, *E. guttatus* and *E. drummondhayi* have identical fin-ray counts and larval spine morphology (Johnson and Keener, 1984). Furthermore, this group cannot be separated from *E. adscensionis* until a full compliment of anal-fin rays are developed. Similarly, *E. niveatus* and *E. flavolimbatus* have identical fin-ray counts and larval spine morphology.

**Sparidae (Porgies)**—With the exception of *Lagodon rhomboides*, treated elsewhere, we collected few sparid larvae, and those (*Calamus* sp(p). and unidentified sparids) were taken in subsurface collections only in May (Append. Table 2). *Pagrus pagrus* was collected on one occasion during February at station 3 (Append. Table 3).

Seven species of sparids are reported from North Carolina recreational and commercial landings (Dixon[3]; Rohde and Francesconi[4]). Two of these, *Calamus bajonado* and *C. proridens*, are uncommon. The other species, *Calamus leucosteus*, *C. nodosus*, *Diplodus holbrooki*, *Pagrus pagrus*, and *Stenotomus caprinus*, are more common. *Calamus leucosteus*, *C. nodosus* and *D. holbrooki* are most abundant in inshore waters (<30 m depth), but *C. nodosus*, which ranks second in sparid landings in North Carolina (Rohde and Francesconi[4]), occurs mainly south of Onslow Bay (Huntsman, 1976; Chester et al., 1984; Parker and Ross, 1986). Our collections of *Calamus* larvae (May) coincide with the spawning season of *C. leucosteus* (April to August, probably with a peak in May [Waltz et al., 1982]) and *C. nodosus* (May and June [Horvath et al., 1990]). We did not identify *Diplodus holbrooki* larvae in our collections, which is puzzling considering the abundance of this species. One species, *P. pagrus*, is extremely important to the commercial and recreational fisheries of North Carolina (Huntsman, 1976; Dixon[3]; Rohde and Francesconi[4]). It is encountered in live-bottom habitats in open-shelf and outer-shelf waters (Grimes et al., 1982; Chester et al., 1984). Rarity of *P. pagrus* larvae in our collections was attributed to inadequate sampling, spatially and temporally. Ripe *P. pagrus* females have been collected January through April, and peak spawning is estimated to be between March and April (Manooch, 1976), a time when we did not sample (Table 1). Furthermore, adults are more commonly captured at depths from 40 to 70 m, whereas our sites were in depths <40 meters. Most recently, Robbins[5] found numerous *P. pagrus* larvae ($n$=252) from samples collected on South Atlantic Bight Recruitment Experiment (SABRE) winter cruises. The majority of larvae (96%) were taken in February, and larvae were most frequently collected between the 25- and 40-m isobaths.

## Estuarine-Dependent Larvae

There were at least 14 species representing seven families of estuarine-dependent larvae collected in Onslow

[5] Robbins, R. E. 1995. Description of larval and juvenile stages of the red porgy, *Pagrus pagrus* (Pisces: Sparidae) from Onslow Bay, North Carolina, U.S.A., with observations on its spatial and temporal distribution. Unpubl. manuscript.

**Table 4**

Density (mean numbers/100 $m^3$) of estuarine-dependent species, by month and station, collected by subsurface tows at live-bottom sites in Onslow Bay, North Carolina. A plus sign (+) following the month indicates samples were collected during that period.

| | | Station | | | |
|---|---|---|---|---|---|
| Family | Taxon | 1 | 2 | 3 | 4 |
| February | | + | + | + | |
| Bothidae | *Paralichthys albigutta* | | | 0.1 | |
| | *P. dentatus* | | | 6.7 | |
| | *P. lethostigma* | | | 0.1 | |
| | *Paralichthys* sp(p). | | | 2.0 | |
| Clupeidae | *Brevoortia tyrannus* | 146.5 | 4.3 | 95.2 | |
| Ophichthidae | *Myrophis punctatus* | 1.8 | | | |
| Sciaenidae | *Leiostomus xanthurus* | 19.3 | 21.4 | 10.0 | |
| | *Micropogonias undulatus* | 1.8 | 2.6 | 1.1 | |
| Sparidae | *Lagodon rhomboides* | 1.8 | 40.0 | | |
| May | | + | + | + | + |
| Bothidae | *Paralichthys albigutta* | | 0.3 | | |
| | *P. dentatus* | 0.3 | 0.2 | 0.4 | |
| | *Paralichthys* sp(p). | 0.3 | 0.2 | | |
| Clupeidae | *Brevoortia tyrannus* | 0.3 | | | |
| Haemulidae | *Orthopristis chrysoptera* | 2.2 | 2.2 | 3.4 | |
| Mugilidae | *Mugil curema* | | 0.3 | 1.1 | |
| | *Mugil* sp(p). | | | | 3.2 |
| Sciaenidae | *Bairdiella chrysoura* | 1.1 | | | |
| | *Cynoscion regalis* | 1.1 | 0.6 | | |
| | *Pogonias chromis* | 0.2 | 0.6 | | |
| August | | + | + | + | |
| Sciaenidae | *Sciaenops ocellatus* | 2.4 | | | |
| September | | + | + | + | |
| Sciaenidae | *Micropogonias undulatus* | | 0.2 | | |
| October | | + | + | + | + |
| Sciaenidae | *Micropogonias undulatus* | 4.7 | 21.3 | 0.4 | |
| November | | + | + | + | |
| Bothidae | *Paralichthys dentatus* | | 1.8 | | |
| | *Paralichthys* sp(p). | | 1.8 | | |
| Mugilidae | *Mugil* sp. | | | 0.2 | |
| Ophichthidae | *Myrophis punctatus* | | | 0.7 | |
| Sciaenidae | *Micropogonias undulatus* | | 135.0 | 0.8 | |

Bay, North Carolina. Larvae were collected at stations 1–3, rarely at station 4 (Table 4). Estuarine-dependent larvae dominated November and February collections. During this period *Brevoortia tyrannus*, *Leiostomus xanthurus*, *Micropogonias undulatus*, and *Lagodon rhomboides* were the dominant estuarine-dependent species collected. These results are in concordance with a previous ichthyoplankton study in Onslow Bay where sampling occurred throughout the winter (Powell and Robbins, 1994), as well as an extensive ichthyoplankton survey throughout the South Atlantic Bight (Powles and Stender, 1976). These results demonstrated that during winter, larvae of estuarine-dependent species (especially *B. tyrannus*, *L. xanthurus*, *M. undulatus*, and *L. rhomboides*) are a major component of the ichthyoplankton in coastal and open-shelf habitats off the Carolinas. Furthermore, *M. undulatus*, which spawns from early September to April (Warlen, 1982; Hettler and Chester, 1990), was the most commonly collected estuarine-dependent species during fall (Table 4).

Larvae of estuarine-dependent species that spawn in sounds, near inlets, and in coastal waters during spring and early summer were collected in May. Larvae of *Orthopristis chrysoptera*, which spawn principally in May in inshore waters (Hildebrand and Cable, 1930), were collected at stations 1–3 (Table 4), suggesting spawning may also occur in open-shelf habitats. Larvae of three species of sciaenids, *Bairdiella chrysoura*, *Cynoscion regalis*, and *Pogonias chromis,* which have similar spatial and temporal spawning habits (Hildebrand and Cable, 1930; Joseph et al., 1964; Mercer, 1983), were collected in limited numbers (Table 4). Hettler and Chester (1990) surveyed waters just inside Beaufort Inlet, NC, and collected small larval *B. chrysoura,* in May and June; *C. regalis,* from May through September; and *P. chromis,* in April and May. These collections are similar to spawning habitats reported by Hildebrand and Cable (1930) and Joseph et al. (1964).

We did not collect larvae of estuarine-dependent species during June and July (Table 4). On the basis of Hildebrand and Cable's (1930) observations on *C. regalis* spawning and Hettler and Chester's (1990) collections, we had expected to collect *C. regalis.*

*Sciaenops ocellatus* larvae were collected in coastal waters (station 1) in August (Table 4). Mercer (1984) speculated that this species spawns along the Atlantic coast, July through December, with a peak in late September or October. Hettler and Chester (1990) collected only three *S. ocellatus* (mean length=5.0 mm) in Beaufort Inlet and these during October.

*Mugil cephalus* and *M. curema* are neustonic and therefore are not taken commonly in subsurface tows (Powles and Stender, 1976; Collins and Stender, 1989; Powell and Robbins, 1994). We collected relatively more *Mugil* larvae in neuston tows than in subsurface tows, but at relatively low densities(<5 larvae/5-min tow). *Mugil curema* were collected in April, May, June, and November (Table 5), and never in coastal waters. Positively identified *Mugil cephalus* larvae were collected only in November; *Mugil* sp(p). collected in February were most likely *M. cephalus.*

*Mugil curema,* which is the most abundant mullet in tropical waters (Robins and Ray, 1986), spawns from March or early April until September with peak spawning April through June in waters beyond the 37-m isobath (Anderson, 1957; Collins and Stender, 1989). To some extent, spawning may occur throughout the year (Collins and Stender, 1989) and is reflected by our collection of *M. curema* in November neuston tows. The collection of small specimens (2–3 mm) off Georgia and South Carolina implies at least some spawning of *M. curema* in the central and northern SAB (Collins and Stender, 1989).

The small numbers of *M. curema* larvae that were collected, especially from April to June, could be attributed to a lack of small larvae and net avoidance by large larvae (>6 mm). Small larvae may not occur in waters off North Carolina as spawning may not occur in this area. Therefore, only larger larvae, more capable of avoiding capture, would be available in the areas sampled.

*Mugil cephalus,* which is the most economically important mullet in eastern United States waters (Robins and Ray, 1986), spawns from North Carolina to Florida seaward of the 37-m isobath. Spawning occurs November through at least April, with peaks in January and February (Anderson, 1958; Collins and Stender, 1989). Small numbers of *M. cephalus* collected (especially in February) could be attributed to our sampling location (landward of the 37-m isobath) and to net avoidance by larger larvae. *Mugil cephalus* is more commonly collected in neuston tows at night, and small larvae (≤6 mm) are rarely collected landward of the 20-m isobath (Collins and Stender, 1989). Hence, larger larvae (>6 mm), which should be more capable of avoiding capture, would be the prevalent life history stage available in the areas we sampled.

## Other Abundant Taxa

Here, we report on the 10 most abundant families of larvae collected in subsurface tows (Table 2). These include the Bothidae, Callionymidae, Carangidae, Clupeidae, Engraulidae, and Ophidiidae. The families Gobiidae, Labridae, Sciaenidae, and Serranidae, also ranked within the top 10, have been documented above.

**Bothidae (Lefteye Flounders)**—*Bothus ocellatus* and *B. robinsi* occur in waters off North Carolina. *Bothus robinsi* and *B. ocellatus* share similar meristic characters and, therefore, positive identification can be made only to the generic level (Gutherz, 1967; Fahay, 1983).

*Bothus* sp(p). larvae were collected during each month of sampling (Table 6) and were most abundant during summer and early fall. They were collected at all open-shelf stations, never at coastal station 1. Large numbers of *Bothus* larvae were collected at station 3 during cruises 14 (20.2/100 $m^3$), 15 (26.9/100 $m^3$), and 18 (23.2/100 $m^3$). This indicated that peak spawning of *Bothus* sp(p). might occur during summer months.

*Bothus* sp(p). appear to spawn throughout the year, based upon length-frequency distributions (Smith et al., 1975). Although *Bothus* larvae have been reported to be most abundant in the SAB in spring and summer and uncommon in winter (Powles and Stender, 1976; Powell and Robbins, 1994; this study), large numbers (majority near the shelf edge) have been collected between Cape Hatteras and Cape Lookout during November and December (Smith et al., 1975).

At least five species of *Citharichthys* were collected but never commonly so (Table 6). The greatest number of *Citharichthys* species was observed in May; collections during other months included very few species.

*Citharichthys arctifrons, C. macrops,* and *C. spilopterus* have been reported to occur in waters off North Carolina. *Citharichthys cornutus* and *C. gymnorhinus* are reported to occur south of North Carolina (Tucker, 1982). South of Onslow Bay, *Citharichthys arctifrons* spawns May–

**Table 5**

The density of intrusion larvae by cruise, collected in subsurface (numbers/100 $m^3$)and neuston tows (numbers/5-min tow) adjacent to live-bottom habitats in Onslow Bay, North Carolina. Intrusion larvae include those classified as oceanic (taxa that are found over the continental slope), outershelf (taxa that commonly inhabit depths of 55–185 m), and other species not classified as outer-shelf or oceanic and that are not known to spawn in coastal or open-shelf waters off North Carolina (designated by an asterisk). Underlined abundance values indicate neuston-tow collections.

| Cruise number | Month year | Family (or suborder) | Species | Relative abundance |
|---|---|---|---|---|
| 1 | Aug/90 | Congridae | Unidentified* | 1.4 |
| 2 | Aug/90 | Ophichthidae | Unidentified* | 0.7 |
| 3 | Sep/90 | Anguillformes | Unidentified | 0.9 |
| | | Ceratoidei | Unidentified | 0.4 |
| | | Nomeidae | *Psenes maculatus* | 0.3 |
| | | Ophichthidae | *Apterichtus ansp** | 0.2 |
| | | | *Callechelys muraena** | 0.3 |
| 5 | Sep/90 | Anguillidae | *Anguilla rostrata** | 0.6 |
| | | Balistidae | *Canthidermis sufflamen* | 1.0 |
| | | Gonostomatidae | *Cyclothone* sp. | 0.5 |
| 7 | Nov/90 | Bothidae | *Engyophrys senta** | 0.9 |
| | | Ophichthidae | *Myrophis punctatus** | 0.9 |
| 9 | Nov/90 | Bothidae | *Citharichthys cornutus** | 0.4 |
| | | Mugilidae | *Mugil curema** | <u>1.0</u> |
| | | Myctophidae | Unidentified | 0.4 |
| | | Ophichthidae | *Myrophis punctatus** | 0.4 |
| 10 | Feb/91 | Anguilliformes | Unidentified * | 1.0 |
| | | Gonostomatidae | *Cyclothone* sp. | 0.5 |
| | | Ophichthidae | *Myrophis punctatus** | 1.8 |
| | | | Ophichthus ocellatus* | 0.2 |
| 12 | May/91 | Caproidae | *Antigonia capros* | 0.2 |
| | | Chlorophthalmidae | Unidentified | 0.2 |
| | | Gonostomatidae | Unidentified | 0.2 |
| | | Mugilidae | *Mugil curema** | <u>2.5</u> |
| | | Myctophidae | Unidentified | 0.9 |
| | | Nomeidae | *Psenes* sp. | 0.2 |
| | | Ophichthidae | *Ophichthus ocellatus** | 0.2 |
| 13 | Jun/91 | Anguilliformes | Unidentified* | 0.7 |
| 14 | Jun/91 | Caproidae | *Antigonia* sp. | 0.1 |
| | | Gonostomatidae | *Cyclothone* sp(p). | 0.6 |
| | | Muraenidae | *Gymnothorax* sp(p).* | 0.2 |
| | | Myctophidae | Unidentified | 0.6 |
| | | Ophichthidae | *Gordiichthys ergodes** | 0.1 |
| | | Serrivomeridae | Unidentified | 0.2 |
| 15 | Jul/91 | Caulophrynidae | *Caulophryne jordani* | 0.2 |
| | | Gempylidae | Unidentified | 0.2 |
| | | Muraenidae | *Gymnothorax* sp(p).* | 0.7 |
| | | Myctophidae | Unidentified | 0.5 |
| | | Photichthyidae | *Vinciguerria nimbaria* | 0.2 |
| 17 | Aug/91 | Congridae | *Rhynchoconger gracilior/guppyi** | 0.4 |
| | | Gonostomatidae | *Cyclothone* sp(p). | 0.9 |
| | | Lobotidae | *Lobotes surinamensis** | <u>0.5</u> |
| | | Myctophidae | Unidentified | 0.5 |
| | | Serranidae | *Psuedogramma gregoryi** | 0.3 |
| 18 | Sep/91 | Balistidae | *Canthidermis* sp. | 0.3 |
| | | Congridae | Unidentified* | 0.3 |
| | | Lobotidae | *Lobotes surinamensis** | <u>0.5</u> |
| 19 | Oct/91 | Anguillidae | *Anguilla rostrata** | 0.1 |
| | | Congridae | Unidentified* | 0.2 |
| | | Muraenidae | Unidentified* | 0.1 |
| | | Ophichthidae | *Apterichtus ansp** | 0.6 |

*continued*

**Table 5 (continued)**

| Cruise number | Month year | Family (or suborder) | Species | Relative abundance |
|---|---|---|---|---|
| 20 | Feb/92 | Bregmacerotidae | *Bregmaceros cantori* | 0.1 |
| | | | *Bregmaceros* type A[1] | 0.4 |
| | | Congridae | Unidentified* | 0.1 |
| | | Gonostomatidae | *Cyclothone* sp. | 0.1 |
| | | Muraenidae | Unidentified* | 0.1 |
| | | Myctophidae | *Hygophum* sp. | 0.1 |
| | | | Unidentified | 0.2 |
| | | Photichthyidae | *Vinciguerria* sp. | 0.1 |
| | | Ophichthidae | *Apterichtus ansp** | 2.3 |
| 21 | May/92 | Bothidae | *Citharichthys gymnorhinus** | 1.1 |
| | | Mugilidae | *Mugil curema** | 0.3 |
| | | Myctophidae | *Unidentified* | 0.3 |
| | | Ophichthidae | *Apterichtus ansp** | 0.3 |
| 22 | Jun/92 | Bothidae | *Citharichthys gymnorhinus** | 0.2 |
| | | Congridae | *Paraconger* sp.* | 0.4 |
| | | Mullidae | *Mugil curema** | 1.0 |
| | | Myctophidae | Unidentified | 1.7 |
| | | Ophichthidae | *Callechelys* sp.* | 0.2 |
| | | Sphyraenidae | *Sphyraena barracuda* | 1.0 |
| 23 | Oct/92 | Bothidae | *Citharichthys gymnorhinus** | 0.2 |
| | | Muraenidae | Unidentified* | 0.3 |
| | | Ophichthidae | *Apterichtus ansp** | 0.9 |
| 24 | Apr/93 | Bothidae | *Citharichthys cornutus** | 0.3 |
| | | Mugilidae | *Mugil curema** | 3.0 |
| 25 | May/93 | Mugilidae | *Mugil curema** | 3.0 |
| | | Myctophidae | Unidentified | 1.3 |
| | | Ophichthidae | *Ophichthus puncticeps** | 0.6 |

[1] Houde (1984).

**Table 6**

The density (numbers/100 $m^3$ summed over all stations) of bothid larvae by month collected by subsurface tows in Onslow Bay, North Carolina. *Paralichthys* larvae are discussed elsewhere (see Table 4).

| | Month | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Taxon | Feb | May | Jun | Jul | Aug | Sep | Oct | Nov |
| *Bothus* sp(p). | 0.1 | 5.3 | 12.9 | 26.9 | 9.8 | 12.8 | 4.2 | 2.0 |
| *Citharichthys arctifrons* | | 0.2 | | | | 0.1 | | |
| *C. cornutus* | | 0.1 | | | | | | 0.2 |
| *C. gymnorhinus* | | 0.4 | 0.1 | 0.2 | | | | |
| *C. macrops* | | 0.1 | | | | | | |
| *C. spilopterus* | 0.9 | 0.2 | | | | | | |
| *Citharichthys* sp(p). | | 1.2 | | | | 1.0 | 0.3 | |
| *Cyclopsetta imbriata* | | 0.3 | 1.4 | 0.2 | 0.9 | 2.6 | | 0.9 |
| *Engyophrys senta* | | | | | | | | 0.5 |
| *Etropus* type A | | 4.0 | 1.1 | 69.7 | | 3.8 | 3.2 | 3.0 |
| *Etropus* type B | 2.0 | 4.3 | 0.1 | | | | 0.4 | 0.9 |
| *Etropus* sp(p). | | 2.2 | 1.1 | | 0.5 | 11.2 | 0.7 | 96.5 |
| *Paralichthys oblongus* | | | 0.3 | | 0.1 | | | 0.2 |
| *Scophthalmus aquosus* | 7.1 | 0.2 | | | | | | |
| *Syacium papillosum* | | 6.1 | 14.5 | 9.0 | 6.6 | 13.9 | 3.7 | 0.4 |

December; *C. cornutus* and *C. gymnorhinus*, January–August and October–November; *C. macrops*, May–September and November; and *C. spilopterus*, September–April (Tucker, 1982). Our collections of larvae generally are in agreement with these reported protracted spawning dates. The occurrence of larval *C. cornutus* and *C. gymnorhinus* in Onslow Bay may be the result of larvae having been transported by Gulf Stream waters.

Groundfish surveys from Cape Fear, NC, to Cape Canaveral, FL, revealed that *C. arctifrons* was one of the most abundant bothids captured but that the greatest percentage of adults (99%) were collected in outer-shelf (64%) and slope (35%) habitats (Wenner et al., 1979 a,b,c,d); occurrence of larvae in shelf habitats in this study could result from cross-shelf transport.

*Cyclopsetta fimbriata* larvae were collected throughout most of the sampling period, but in small numbers (Table 6). Larval *C. fimbriata* are rarely collected as larvae north of Cape Hatteras (Smith et al., 1975). Larvae have been commonly collected during winter and spring in the SAB (Powles and Stender, 1976), yet we collected them in summer and fall, not winter. Gutherz (1970) collected *C. fimbriata* larvae from Jupiter Inlet, FL, to Cape Hatteras, NC, and they were almost solely collected May to October, similar to our collection dates. Gutherz (1970) suggested a bimodal spawning period with peaks in June and September; based upon collections of small *C. fimbriata*, spawning most likely occurred within the 50-m isobath.

*Engyophrys senta* larvae were rarely collected (Table 6). They are distributed in the Florida Keys, Bahamas, Gulf of Mexico, and Caribbean Sea, and are most likely transported to continental shelf waters by Gulf Stream intrusions.

*Etropus* larvae were often collected but we were not able to identify any to species (Table 5). The three largest collections of *Etropus* were made at station 2 in November (96.5 larvae/100 $m^3$), July (69.7 larvae/100 $m^3$) and September (11.0 larvae/100 $m^3$). Based upon the distribution and spawning of adults (Leslie and Stewart, 1986), *Etropus* Type A larvae collected during June and July were most likely *E. crossotus*. Larvae collected during fall, winter, and spring were likely *E. cyclosquamus* or *E. rimosus* (or both), based upon the distribution and spawning times of the adults (Leslie and Stewart, 1986). *Etropus cyclosquamus* and *E. rimosus* are abundant on the shelf south of Cape Hatteras.

*Paralichthys oblongus* larvae were rarely collected (Table 5). Larval *P. oblongus* are most abundant north of Cape Hatteras, NC, even though adults range as far south as Florida (Gutherz, 1967; Smith et al., 1975). *Paralichthys oblongus* is a spring spawner, with spawning progressing northward as water temperatures increase (Smith et al., 1975). Collections in June, August, and November indicate that these larvae were spawned outside of our study area. The lack of specimens in our collections, compared with those made north of Cape Hatteras (Smith et al., 1975), indicates that spawning is minimal in Onslow Bay, NC.

*Scophthalmus aquosus* larvae were collected during winter and spring (Table 6) with the largest collection (7.0 larvae/100 $m^3$) taken at station 1 in February. A previous ichthyoplankton survey reported *S. aquosus* in Onslow Bay coastal and inner-shelf waters during December (Powell and Robbins, 1994), but this species was not reported in Powles and Stender's (1976) survey of the SAB. This species, which ranges from Nova Scotia to Florida, from shore to the 45-m isobath (Gutherz, 1967), appears to be most abundant in the Middle Atlantic Bight (MAB) (Smith et al., 1975). A spring spawning has been reported south of Chesapeake Bay, advancing seasonally in a northward progression and recommencing off Virginia and North Carolina in the fall (Smith et al. 1975). The occurrence of specimens in these collections and in those of Powell and Robbins (1994) is in agreement with the above spawning times.

*Syacium papillosum* larvae were abundant from spring to winter (Table 6) and were collected at all stations except in coastal waters (station 1). *Syacium papillosum* larvae appear to be abundant throughout the SAB in all seasons except winter (Powles and Stender, 1976; Powell and Robbins, 1994) but rarely occur north of Cape Hatteras (Smith et al., 1975). The distribution of larvae mirror the adult range of *Syacium papillosum*, North Carolina to Florida. Collections of large numbers of larvae, May through October (Smith et al. 1975), between Cape Hatteras and Cape Lookout, along with collections in Onslow Bay (this present study) and other collections in the SAB (Powles and Stender, 1976), suggest a protracted peak-spawning period of May to October.

**Callionymidae (Dragonets)**—*Diplogrammus pauciradiatus* larvae dominated callionymid collections (Table 7). They were collected in all months sampled except February, and generally were most abundant in July and September. Largest collections (> 10.0 larvae/100 $m^3$) were taken in September 1990 at stations 2 (77.6 larvae/100 $m^3$) and 3 (21.5 larvae/100 $m^3$); October 1990 at station 2 (22.8 larvae/100 $m^3$); July 1991 at station 2 (144.7 larvae/100 $m^3$); and September 1991 at station 2 (14.4 larvae/100 $m^3$). Larvae were collected at station 1 on only one occasion (May 1991; 0.4 larvae/100 $m^3$). These collections indicate that *D. pauciradiatus* spawns intensively in open-shelf waters, but not in coastal waters.

*Paradiplogrammus bairdi* larvae were also collected in all months sampled except February, occurring in low numbers (Table 7). They were never collected at station 1, and on only one occasion at station 2 (Jun 1992; 0.4 larvae/100 $m^3$). Our findings agree with those of

**Table 7**
The density (numbers/100 $m^3$ summed over all stations) of selected families by month collected by subsurface tows in Onslow Bay, North Carolina.

| | Month | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Taxon | Feb | May | Jun | Jul | Aug | Sep | Oct | Nov |
| Callionymidae | | | | | | | | |
| *Diplogrammus pauciradiatus* | | 1.9 | 3.0 | 147.4 | 6.3 | 61.8 | 10.0 | 4.5 |
| *Paradiplogrammus bairdi* | | 0.1 | 0.4 | 0.2 | 0.8 | 1.2 | 0.1 | 1.1 |
| Unidentified | | | | | 0.7 | 0.1 | | |
| Carangidae[1] | | | | | | | | |
| *Caranx bartholomaei* | | 0.1 | | | | | | |
| *C. crysos* | | | | 1.5 | 0.2 | | | |
| *Caranx* sp(p). | | 0.3 | | | 1.7 | 0.3 | | |
| *Decapterus punctatus* | | 22.4 | 33.6 | 244.0 | 13.6 | 14.0 | 4.4 | 0.2 |
| *Elagatis bipinnulata* | | 0.1 | | | | | | |
| *Selar crumenophthalmus* | | 0.2 | 0.2 | | | | | |
| *Trachinotus carolinus* | | 0.2 | | | | | | |
| Unidentified | | 1.2 | 1.1 | 2.2 | 2.7 | 6.2 | 1.2 | 1.0 |
| Clupeidae[2] | | | | | | | | |
| *Etrumeus teres* | 7.3 | | | | | | | 0.2 |
| *Harengula jaguana* | | | | | 0.3 | | | |
| *Opisthonema oglinum* | | 0.1 | | | | | | |
| *Sardinella aurita* | | 0.2 | | 28.6 | 17.7 | 4.9 | 0.1 | |
| Unidentified | | 2.7 | 430.2 | 2.0 | 18.8 | 3.9 | | |
| Engraulidae | | | | | | | | |
| *Anchoa hepsetus* | 0.1 | 8.4 | | | 19.7 | 820.0 | 2.2 | 4.2 |
| *Engraulis eurystole* | | | 0.9 | | | | 0.3 | |
| Unidentified | | 1.2 | 3.2 | | 529.9 | 1.0 | | |
| Ophidiidae | | | | | | | | |
| *Ophidion beani* | | 3.7 | 0.2 | 11.0 | 0.2 | 2.6 | | |
| *O. holbrooki* | 0.5 | 0.7 | 0.3 | | | 0.5 | 0.4 | |
| *O. marginatum* | | | 0.2 | | | 0.5 | | 26.1 |
| *O. robinsi* or *grayi* | 2.4 | 2.8 | 0.7 | 0.8 | | | 0.2 | |
| *O. selenops* | | 3.7 | 11.0 | 22.0 | 21.0 | 50.3 | 13.1 | 11.5 |
| *O. welshi* | | 0.5 | | | | | | |
| *Ophidion* spp. | | | 0.7 | | | | | |
| *Otophidium omostigmum* | | 2.5 | 1.2 | 7.8 | | | 0.9 | 0.2 |
| Unidentified | 0.9 | 8.2 | 7.0 | 0.2 | 1.1 | 3.7 | 4.5 | 5.1 |

[1] *Seriola* is discussed elsewhere (see Append. Table 3).
[2] *Brevoortia tyrannus* is discussed elsewhere (see Table 4).

Olney and Sedberry (1983) who found *D. pauciradiatus* larvae to be an important component of ichthyoplankton collections in the SAB, especially in late summer and early fall. Adults appear to inhabit middle and outer shelf depths off the Carolinas and to spawn in summer and fall. Olney and Sedberry collected small numbers of *P. bairdi*, primarily at outer-shelf stations close to the main axis of the Gulf Stream and concluded that adults may be rare or absent in the SAB and that larvae originate from tropical populations.

**Carangidae (Jacks)**—Twenty-two species of carangids (excluding *Seriola* sp(p)., which are discussed with reef fish species) are reported from waters off North Carolina (Robins and Ray, 1986; Schwartz, 1989). Of these, six species were positively identified (Table 7). Only two of the five species of *Caranx* found off North Carolina (*C. bartholomaei*, and *C. crysos*) were positively identified, and they were rarely collected. Berry (1959) reported that in the SAB, larval and juvenile *C. ruber* have the widest distribution; *C. crysos* are most abundant; *C. bartholomaei* are restricted in both occurrence and numbers; and *C. latus* and *hippos* are scarce. Collections of juveniles in the SAB by Fahay (1975) and in waters off North Carolina by Settle (1993) confirm Berry's observations. The scarcity of larval *Caranx* in our study is explained by the spawning habits of the adults (Berry, 1959). Most spawning occurs February through September in Gulf Stream waters or waters contributing to it. Some recruitment may result from spawning within the SAB, but the majority of recruits are apparently from waters around southern Florida, Cuba, and the Bahamas, as well as from the eastern Gulf of Mexico and northern Caribbean (Berry, 1959).

*Decapterus punctatus* larvae were abundant, particularly from May through September (Table 7). Larvae were collected at all stations, and the three largest collections (July 1991, 239.4 larvae/100m$^3$ ; May 1991, 60.9 larvae/100m$^3$ ; and June 1991, 40.6 larvae/100m$^3$) were all taken at station 2. Two notable collections were made by neuston tows in September 1991 (22.5 larvae/5-min tow) and Oct 1992 (26.0 larvae/5-min tow) at station 2. Based upon our collections, *D. punctatus* has a protracted spawning period in open-shelf waters off North Carolina with peak spawning from late spring through mid-summer. Hales (1987), on the basis of gonad analyses, reported that *D. punctatus* spawns in the SAB from March through August and to lesser extent throughout the year.

*Elagatis bipinnulata* larvae were collected on one occasion (May 1991) at station 3 (Table 7). This species apparently spawns in oceanic waters south of the SAB (Fahay, 1975).

*Selar crumenophthalmus* larvae were collected on two occasions (May 1991 and June 1992) at station 3 (Table 7). Little life history information is known for this species in the northwestern Atlantic Ocean and Gulf of Mexico, and few larvae have been reported in the SAB and Caribbean (Powles and Stender, 1976; Richards, 1984).

*Trachinotus carolinus* larvae were collected on one occasion (May 1993) at station 3 (Table 7); it apparently spawns in Gulf Stream waters. Waves of 13–18 mm fish have been reported to occur on Georgia beaches during the last half of April, or first half of May (Fields, 1962). *Trachinotus falcatus*, also reported from North Carolina waters (Robins and Ray, 1986), apparently spawns in waters in close proximity to or in the Gulf Stream. It has been reported to arrive on Georgia beaches (not in waves like *T. carolinus*) in late May or early June at sizes of 18–44 mm (Fields, 1962). Hettler and Barker (1993) collected 11.0-mm *T. falcatus* at Ocracoke Inlet, NC, during July and August, suggesting that immigration to coastal waters proceeds from south to north as the season progresses. *Trachinotus goodei*, although reported from waters off North Carolina (Robins and Ray, 1986), appears to be rare along the south Atlantic coast (Fields, 1962), apparently spawning south of the SAB (Fahay, 1975).

**Clupeidae (Herrings)**—We positively identified larvae of four species of clupeids (Table 6). *Etrumeus teres* larvae were collected at station 2 and station 3 in late fall and winter. A detailed account of the distribution and abundance of this pelagic species in Onslow Bay from late fall to early spring was reported by Powell and Robbins (1994).

*Harengula jaguana* and *Opisthonema oglinum* were collected on one occasion at station 3 (Table 7). There is a paucity of life history information on both species in the SAB. *Opisthonema oglinum* apparently spawn in May and June in waters off North Carolina (Hildebrand, 1964) and adults have been reported to migrate south from North Carolina waters in autumn (Pristas and Cheek, 1973). Hettler and Barker (1993) collected numerous *O. oglinum* from June through August at Oregon Inlet, NC, north of our study site, indicating spring and summer spawning in that area. *Sardinella aurita* larvae were collected during summer and early fall (Table 7). The two largest collections were taken during August 1990 (31.9 larvae/100 m$^3$ at station 2) and July 1991 (28.6 larvae/100 m$^3$ at station 3). There is little life history information on this species in the SAB. Spawning off Florida has been reported to occur from September to February (Fahay, 1983). On the other hand, we collected larvae indicating summer spawning.

**Engraulidae (Anchovies)**—*Anchoa hepsetus* larvae were the only *Anchoa* identified to species. Larvae were most abundant in September (Table 7). The largest single collection (1,623 larvae/100 m$^3$) was at station 1 in September 1990 (cruise 4). The largest collection of unidentified engraulid larvae was most likely *A. hepsetus.* Peak spawning of *A. hepsetus* in waters off North Carolina has been reported to occur in May (Hildebrand and Cable, 1930). Hettler and Chester (1990) collected small ($<$12.0 mm mean SL) *A. hepsetus* July through September in an inlet tidal pass near Beaufort Inlet, NC, suggesting (as did our data) that peak spawning is in late summer and early fall. They, however, collected numerous small ($\leq$6.8 mm mean SL) unidentified engraulids ($n$=71,735 larvae) April through June.

*Engraulis eurystole* larvae were rarely collected (Table 6). This species, which has North Carolina as its southernmost range of abundance (Robins and Ray, 1986), has been reported to spawn in July and October (Fahay, 1983). We collected larvae in June and October (Table 6), suggesting a more protracted spawning season or confusion with other engraulid species. *Anchoviella perfasciata* and *Engraulis eurystole* share similar overlapping dorsal- and anal-fin positions and meristics, hence larvae can be confused, especially since the spawning season of *A. perfasciata* is unknown (Farooqi et al., 1995).

**Ophidiidae (Cusk-Eels)**—*Ophidion selenops* was the most commonly collected larval ophidiid (Table 7). It was collected at all stations, during all months except February. The largest collection of *O. selenops* (54.3 larvae/100m$^3$) occurred at station 2, September 1991. Based upon our collections, spawning appeared to be protracted with peak spawning apparently during summer and early fall. Adult *O. selenops* have been reported to occur in coastal, open and outer shelf habitats (Wenner et al., 1979 a,b,c,d; Robins and Ray, 1986). *Ophidion selenops* adults ranked fifth in numerical abundance in Wenner's ophidiid trawl collections in the SAB but, given the small adult size of this species (to 10 cm) (Robins and Ray, 1986) and the abundance of larvae, this species may be more abundant than trawl surveys indicate.

*Ophidion marginatum* larvae were collected on three cruises in June, September, and November (Table 7) and only at station 2. One notable collection (52.1 larvae/100m$^3$) was in November 1990. Based upon our collections and collections from the MAB (Fahay, 1992), spawning for this species appears to peak in late summer in the MAB, fall in the SAB. Based upon developmental stages and depth of capture, Fahay (1992) speculated that larvae overwinter in benthic habitats on the continental shelf and enter estuaries in the early spring. This species ranked third in abundance in Wenner's (1979 a,b,c,d) ophidiid trawl collections in the SAB, with 90% of specimens collected in open-shelf habitats.

*Ophidion beani* larvae were collected at stations 2–4, May through September (Table 6), suggesting that it spawns during spring and summer in Onslow Bay. It is one of the most abundant ophidiids in the SAB (Wenner et al., 1979 a,b,c,d) and appears over the entire continental shelf. However, the majority (76%) of adult *O. beani* collected by Wenner et al. in the SAB were from open-shelf habitats.

*Otophidium omostigmum* larvae were collected at station 2–4, May to July, and again in October and November (Table 7). Although small numbers of larvae were collected, adults appear to be common in open-shelf habitats in the SAB as indicated by trawl surveys (Wenner et al., 1979 a,b,c,d).

*Ophidion robinsi/grayi* were collected at stations 2–4 in small numbers (Table 7). Using meristic characters from cleared and stained material, we positively identified one specimen of *O. grayi* in May and one specimen of *O. robinsi* in October. Powell and Robbins (1994) positively identified *O. grayi* larvae in February and March. Fahay (1992) reported that *O. robinsi* are summer spawners. On this basis, the undeveloped larvae collected in winter could be *O. grayi* while those collected in summer could be *O. robinsi.*

*Ophidion holbrooki* and *O. welshi* were rarely collected (Table 7). Adult *O. holbrooki* were abundant ($n$=349) in trawl surveys in the SAB (Wenner et al., 1979 a,b,c,d) in coastal (36%), open-shelf (57%), and outer-shelf (7%) habitats. Adult *O. welshi*, on the other hand, were not collected by Wenner et al., even though this species is reported to range from Georgia southward (Robins and Ray, 1986).

## Larval Evidence of Gulf Stream Intrusions

We considered that the presence of larvae classified as 1) oceanic (species that are found over the continental slope), 2) other (species not classified as outer-shelf or oceanic but that are not known to spawn in coastal or open-shelf waters off North Carolina), or 3) outer shelf (species that commonly inhabit depths of 55–185 m) at our sampling sites is a result of the intrusion (cross-shelf transport) of Gulf Stream filaments, created by the meandering of the northward flowing Gulf Stream, onto the continental shelf (Pomeroy et al., 1993; Verity et al., 1993). We defined these as intrusion larvae.

Intrusion larvae were collected on numerous cruises (Table 5), especially at station 3. Oceanic and outer-shelf larvae were collected on one occasion at station 2 (cruise 5—*Canthidermis sufflamin* and *Cyclothone* sp.), on one occasion at station 4 (cruise 25— Myctophidae), and never at station 1. Larvae classified as "others" were collected at all stations, during all seasons. (Table 5).

Occurrence of larvae representing oceanic and outer-shelf species in Onslow Bay was documented by the authors in a previous study undertaken during late fall, winter, and early spring (Powell and Robbins, 1994). In that study, larvae from oceanic and outer-shelf species were encountered in open-shelf habitats throughout the sampling period. Powell and Robbins (1994) concluded that the occurrence of these species might indicate the intrusion of warm Gulf Stream waters onto the shelf. In this study, the occurrence of intrusion larvae throughout the year suggested that Gulf Stream waters intrude as filaments upon the open shelf during all seasons. This process, then, cannot be overlooked in terms of providing recruits from subtropical and tropical waters to live-bottom habitats in waters off North Carolina.

Intrusions of Gulf Stream water into live-bottom habitats was documented at station 3. Periodically from 14 November 1991 through 17 August 1994 bottom-temperature data were obtained from a data logger placed at station 3. The data indicated that during these periods, when a cross-shelf temperature gradient existed, filaments of warm water moved into this area (Fig. 7). These were not isolated events, rather they occurred frequently, and temperatures changed as much as 7°C in a 3-day period (19–22 December 1992). Temperature data at station 3 during a six-day period (17–22 December 1991) depicted the intrusion of two Gulf Stream filaments during that period. Satellite images (advanced very high resolution radiometer [AVHRR]) available for only 17, 18, and 22 December 1991 depicted warmwater filaments encroaching on station 4 on the 17th, and station 3 on the 18th (Fig. 8). Another filament begin to encroach on station 3 on 20 December, and on 22 December warm Gulf Stream water influenced water temperatures at stations 2–4.

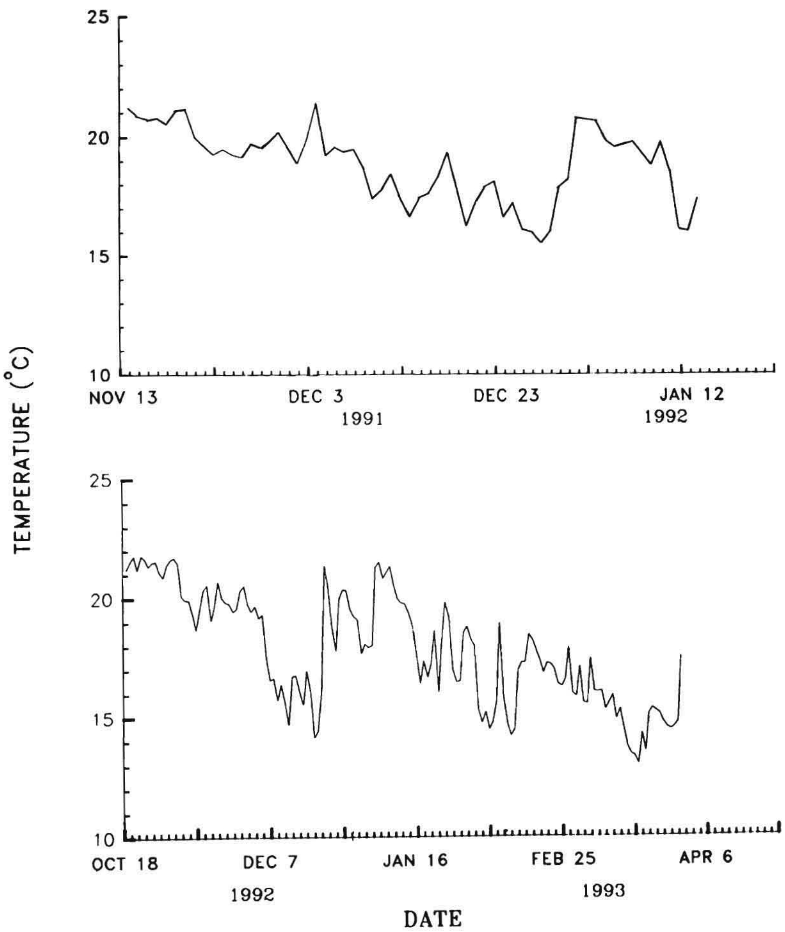


**Figure 7**
Average daily bottom-water temperatures at station 3 (34°14.6'N, 76°35.5'W) during the period 14 November 1991 to 14 January 1992 and 29 October 1992 to 30 March 1993.

The northward transport of tropical larvae by the Gulf Stream and movement onto the shelf by cross-slope flow have been examined by Hare and Cowen (1991). They suggest that larvae of *Xyrichtys* (=*Hemipteronotus*) *novacula* are expatriated to the MAB from populations spawning south of Cape Hatteras by means of the northward Gulf Stream flow, with subsequent advections onto the shelf by a cross-slope flow associated with warm-core rings. Our frequent collections of larvae from "oceanic," "outer-shelf," and "other" species (Powell and Robbins, 1994; this study) reinforced the suggestion that the presence of these taxa can be explained by Gulf Stream flow or cross-shelf advection of filaments (or both) created by Gulf Stream meanders. The influence of such processes is difficult to evaluate but must be considered as one of several processes that influences recruitment of reef fishes to North Carolinian waters.

## Conclusions

Larvae from 22 families with reef-associated taxa were collected adjacent to live-bottom habitats in Onslow Bay, NC. Commonly collected reef-associated taxa included the balistid *Monacanthus hispidus*, the blenniid *Parablennius marmoreus*, the gobiid *Ioglossus calliurus*, the haemulids *Haemulon* sp(p). (*H. aurolineatum* or *H. plumieri* [or both]), the labrid *Hemipteronotus novacula*, the lutjanid *Rhomboplites aurorubens*, and the serranids *Centropristis* sp(p). (most likely *C. striata*), *Diplectrum formosum*, and Serraninae type A (*C. ocyurus*?). Our collections indicated that these taxa spawn in Onslow Bay and this spawning could provide recruits locally.

Many other life history types co-occurred with reef-associated taxa. These included: 1) estuarine-dependent species that dominated late fall and winter collections, 2) coastal pelagic species dominated by engraulid larvae, 3) open-shelf pelagic species dominated by clupeid and carangid larvae, 4) open-shelf demersal species dominated by bothid and callionymid larvae, and 5) outer-shelf and oceanic species which, along with other species that are not known to spawn in Onslow Bay, indicated intrusion of Gulf Stream waters on the open shelf.

This ichthyoplankton study has limitations in obtaining information on reef fish recruitment. Sampling during daylight hours with paired bongo nets is suitable to obtain early-stage larvae (i.e. preflexion and flexion stages) that can provide general information on spatial and temporal spawning. Older larvae or juveniles, competent to settle on live-bottom habitat, are rarely encountered, however, and estimates of the duration of the pelagic stage and size at settlement cannot be obtained. Identification of early-stage larvae is difficult, impeding our understanding of early life studies because of lack of taxonomic descriptions.

Results from this study suggest that future studies examining the recruitment of fishes to live-bottom habitats should include: 1) intensive day and night sampling in late spring and summer (when many reef-associated species appear to spawn) over the continental shelf and Gulf Stream waters, using sampling gear that can assess quantitatively the relative abundance of larger ichthyoplankton (e.g. Methot frame trawl, [Methot, 1986]), along with standard ichthyoplankton gear (MOCNESS, Tucker trawl, opening and closing bongo nets) that will provide depth-discrete samples of smaller ichthyoplankton; 2) a description of the hydrologic circulation pattern in Onslow Bay during late spring and summer to test the generalization that circulation patterns result in the retention of eggs and larvae within the Bay; 3) collection of recently settled juveniles at live-bottom habitats accessible to SCUBA divers for otolith analysis to estimate planktonic duration, growth, and age at settlement that, when used with physical data, could provide an insight into the origin of larvae; and 4) greater ability to identify laboratory-reared larvae to species with biochemical techniques.


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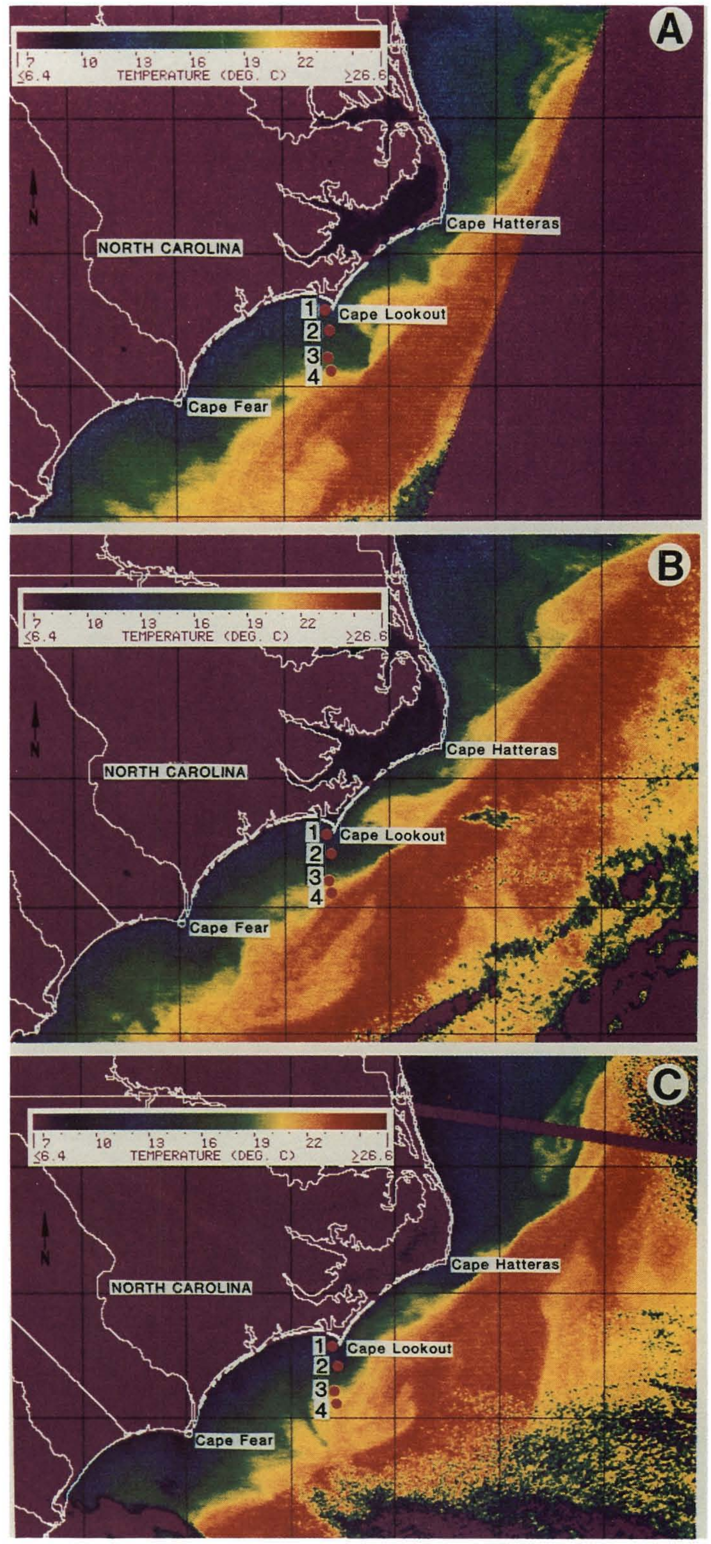


**Figure 8**
Sea-surface temperature satellite imagery on (A) 17 December, (B) 18 December, and (C) 22 December 1991 off North Carolina. Station locations are referenced.

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**Appendix Table 1**
Surface water temperatures (°C) at live-bottom sites in Onslow Bay, North Carolina.

| Cruise number | Date | Station 1 | Station 2 | Station 3 | Station 4 |
|---|---|---|---|---|---|
| 10 | 4–11 Feb 1991 | 11.4 | 13.5 | 17.1 | |
| 20 | 1 Feb 1992 | | | 16.6 | |
| 11,12 | 21–23 May 1991 | 20.2 | 22.3 | 25.5 | |
| 21 | 13 May 1992 | | 18.6 | 18.2 | |
| 24,25 | 1–3 May 1993 | | | 22.6 | 21.0 |
| 13,14 | 4–11 Jun 1991 | 25.2 | 25.3 | 25.6 | |
| 22 | 1 Jun 1992 | | 22.6 | 23.3 | 24.2 |
| 15,16 | 11–12 Jul 1991 | 28.7 | 28.7 | 28.4 | |
| 1,2 | 16–29 Aug 1990 | 31.0 | 28.0 | 28.5 | |
| 3,4,5 | 11–25 Sept 1990 | 26.6 | 27.5 | 27.8 | |
| 18 | 18 Sept 1991 | ND | ND | ND | |
| 6 | 3 Oct 1990 | | 25.8 | 26.7 | |
| 19 | 8–13 Oct 1991 | 21.6 | 22.5 | 24.8 | |
| 23 | 26 Oct 1992 | | 21.1 | 22.2 | 23.4 |
| 7,8 | 1–5 Nov 1990 | 20.0 | 20.9 | 23.4 | |
| 9 | 27 Nov 1990 | 21.1 | 16.4 | 21.1 | |

**Appendix Table 2**
The density (numbers/100 $m^3$) of reef fish larvae by month and station collected by subsurface tows in Onslow Bay, North Carolina. A plus sign (+) following the month indicates samples were taken during that period. Pelagics are excluded.

| Family | Taxon | Station 1 | Station 2 | Station 3 | Station 4 |
|---|---|---|---|---|---|
| February | | + | + | + | |
| Congridae | Unidentified | | | 0.1 | |
| Labridae | Unidentified | | | 0.5 | |
| Scaridae | Unidentified | | | 0.1 | |
| Serranidae | *Anthias* sp. | | | 0.1 | |
| | *Diplectrum formosum* | | | 0.1 | |
| May | | + | + | + | + |
| Acanthuridae | *Acanthurus* sp. | | | 0.2 | |
| Apogonidae | Unidentified | | 0.2 | 4.5 | |
| Balistidae | *Monacanthus hispidus* | | 0.2 | 0.3 | |
| | Unidentified | | | 2.2 | |
| Blenniidae | *Parablennius marmoreus* | 0.6 | | | |
| Gobiidae | *Ioglossus calliurus* | | | 11.5 | |
| | Type A | | | 0.7 | |
| Haemulidae | *Haemulon* sp(p). | | 6.9 | 0.2 | |
| Labridae | *Hemipteronotus* sp(p). | | 0.1 | 0.1 | |
| | Unidentified | | | 3.0 | |
| Lutjanidae | *Lutjanus* sp. | | | 0.3 | |
| | *Rhomboplites aurorubens* | | | 0.1 | |
| Mullidae | Unidentified | | | 0.1 | |
| Pomacanthidae | *Holacanthus* sp. | | | 0.1 | |
| Pomacentridae | Unidentified | | | 0.1 | |
| Priacanthidae | Unidentified | | | 0.8 | |
| Scaridae | Unidentified | | 0.1 | 0.3 | |

*continued*

**Appendix Table 2 (continued)**

| Family | Taxon | Station 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Serranidae | Anthiinae | | | 0.1 | |
| | *Centropristis* sp(p). | | 13.8 | 0.4 | |
| | *Diplectrum formosum* | | 8.2 | 0.2 | |
| | *Epinephelus* sp. | | | 0.4 | |
| | *Serraninae* type A. | | 1.2 | | |
| | Serraninae | | 0.1 | | |
| Sparidae | *Calamus* sp(p). | | | 1.0 | |
| | Unidentified | 1.2 | | 0.8 | |
| June | | + | + | + | + |
| Apogonidae | Unidentified | | 0.2 | 0.7 | 2.8 |
| Balistidae | *Aluterus* sp. | | | 0.1 | |
| | *Monacanthus hispidus* | | 0.6 | 0.7 | 2.8 |
| | *Monacanthus* sp(p). | 3.4 | | 0.2 | |
| | Unidentified | | | 2.2 | |
| Chaetodontidae | *Chaetodon* sp. | | | 0.3 | |
| Gobiidae | *Ioglossus calliurus* | | 2.9 | 8.7 | 7.9 |
| | Type A | | 0.7 | 1.6 | 0.8 |
| Haemulidae | *Haemulon* sp(p). | | 1.8 | 0.1 | |
| Holocentridae | *Holocentrus* sp. | | | 0.2 | |
| Labridae | *Hemipteronotus* sp(p). | | | | 3.5 |
| | Unidentified | | 101.1 | 13.0 | |
| Lutjanidae | *Lutjanus* sp(p). | | | 1.1 | 0.6 |
| | *Rhomboplites aurorubens* | | | 1.9 | 0.4 |
| Muraenidae | *Gymnothorax* sp. | | | 0.1 | |
| Pomacanthidae | *Holacanthus* sp. | | | 0.1 | |
| Pomacentridae | *Abudefduf saxatilis* | | | 0.7 | |
| | *Chromis* sp. | | | 0.1 | |
| | *Pomacentrus* sp. | | | 0.1 | |
| | Unidentified | | 0.2 | 0.2 | 2.0 |
| Priacanthidae | *Pristigenys alta* | | | 0.5 | 0.4 |
| | Unidentified | | | 0.3 | |
| Scaridae | Unidentified | | 0.2 | 0.2 | |
| Serranidae | *Anthias* sp. | | | | 0.4 |
| | *Centropristis* sp. | | 1.4 | 0.8 | 1.2 |
| | *Diplectrum formosum* | | 2.4 | 0.6 | |
| | *Epinephelus* sp. | | | 0.1 | |
| | *Liopropoma* sp. | | | | 0.4 |
| | *Rypticus* sp. | | | 0.1 | |
| | Serraninae type A | | 1.8 | 0.5 | 0.4 |
| | Serraninae | | | 0.1 | |
| | *Serranus* sp(p). | | | 0.2 | |
| | Unidentified | | | 0.1 | 0.4 |
| July | | + | + | + | |
| Apogonidae | Unidentified | | | 3.2 | |
| Balistidae | *Aluterus* sp(p). | | | 0.5 | |
| | *Monacanthus* sp(p). | | | 0.8 | |
| | Unidentified | | 6.8 | 0.9 | |
| Chaetodontidae | *Chaetodon* sp. | | | 0.9 | |
| Gobiidae | *Ioglossus calliurus* | | | 199.7 | |
| Haemulidae | *Haemulon* sp(p). | | 53.0 | | |
| Labridae | Unidentified | | 566.7 | 7.8 | |
| Lutjanidae | *Lutjanus* sp(p). | | | 29.8 | |
| | *Rhomboplites aurorubens* | | | 5.4 | |
| Malacanthidae | Unidentified | | | 0.2 | |

*continued*

**Appendix Table 2 (continued)**

| Family | Taxon | Station 1 | Station 2 | Station 3 | Station 4 |
|---|---|---|---|---|---|
| Muraenidae | *Gymnothorax* sp(p). | | | 0.7 | |
| Pomacentridae | *Pomacentrus* sp. | | | 0.4 | |
| Priacanthidae | Unidentified | | | 0.4 | |
| Serranidae | *Centropristis* sp(p). | | 20.5 | | |
| | *Diplectrum formosum* | | 6.8 | | |
| | *Rypticus* sp(p). | | 3.0 | | |
| | Serraninae type A | | 22.0 | | |
| | *Serranus* sp. | | | 0.5 | |
| August | | + | + | + | |
| Balistidae | *Aluterus shoepfi* | | 0.2 | | |
| | *Aluterus* sp. | | | 0.1 | |
| | *Monacanthus ciliatus* | | | 0.1 | |
| | Unidentified | | 1.1 | 0.5 | |
| Chaetodontidae | Unidentified | | | 0.1 | |
| Gobiidae | *Ioglossus calliurus* | | 13.2 | 9.7 | |
| | Type A | | 0.3 | 0.8 | |
| | Type C | | | 0.2 | |
| Labridae | Unidentified | | 0.7 | 0.3 | |
| | *Hemipteronotus* sp(p). | | 0.4 | 1.0 | |
| Lutjanidae | *Lutjanus* sp(p). | | 3.0 | 0.4 | |
| | *Pristipomoides aquilonaris* | | | 0.2 | |
| | *Rhomboplites aurorubens* | | 6.0 | 0.4 | |
| Priacanthidae | *Pristigenys alta* | | | 0.1 | |
| | Unidentified | | 0.1 | 0.6 | |
| Rachycentridae | *Rachycentron canadum* | | 1.4 | | |
| Scaridae | *Sparisoma* sp(p). | | | 1.2 | |
| Serranidae | *Centropristis* sp. | | 0.1 | | |
| | *Epinephelus* sp. | | 0.1 | | |
| | *Pseudogramma gregoryi* | | 0.1 | | |
| | *Rypticus* sp(p). | | 5.7 | 1.0 | |
| | Unidentified | | | 0.2 | |
| September | | + | + | + | |
| Apogonidae | Unidentified | | | 0.5 | |
| Balistidae | *Aluterus shoepfi* | | | 0.1 | |
| | *Aluterus* sp(p). | | 0.4 | | |
| | *Canthidermis* sp. | | | 0.1 | |
| | *Canthidermis sufflamen* | | 0.5 | | |
| | *Monacanthus ciliatus* | | | 0.4 | |
| | *Monacanthus hispidus* | | | 3.2 | |
| | Unidentified | | 0.2 | 2.9 | |
| Congridae | Unidentified | | | 0.1 | |
| Gobiidae | *Ioglossus calliurus* | | | 91.7 | |
| | Type A | | 27.3 | 1.5 | |
| Labridae | Unidentified | | 1.1 | 3.9 | |
| | *Hemipteronotus* sp(p). | | 1.1 | 3.0 | |
| Lutjanidae | *Lutjanus* sp(p). | | | 4.8 | |
| | *Rhomboplites aurorubens* | | 0.6 | 3.1 | |
| Pomacentridae | Unidentified | | | 0.1 | |
| Priacanthidae | Unidentified | | | 1.0 | |
| Scaridae | *Sparisoma* sp(p). | | | 0.4 | |
| | Unidentified | | 0.2 | 12.3 | |
| Serranidae | *Centropristis* sp(p). | | 0.3 | 0.1 | |
| | *Diplectrum formosum* | | 0.5 | | |
| | *Epinephelus cruenatus* | | | 0.5 | |

*continued*

**Appendix Table 2 (continued)**

| Family | Taxon | Station 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| | Epinephelini | | | 0.1 | |
| | *Rypticus* sp(p). | | 0.2 | 0.4 | |
| | Serraninae | 0.4 | | 0.2 | |
| | Serraninae type A | | 1.3 | 0.1 | |
| | *Serranus* sp(p). | | | 0.2 | |
| | Unidentified | | | 0.1 | |
| October | | + | + | + | + |
| Apogonidae | Unidentified | | | 0.3 | |
| Balistidae | *Aluterus* sp(p). | 0.3 | | 0.1 | |
| | *Monacanthus ciliatus* | | | 0.1 | |
| | *Monacanthus hispidus* | | | 0.5 | |
| | *Monacanthus* sp. | | | 0.1 | |
| | Unidentified | | | 0.5 | |
| Congridae | Unidentified | | | 0.1 | |
| Gobiidae | *Gobiosoma* sp. | | 0.2 | | |
| | *Ioglossus calliurus* | | | 16.6 | 1.3 |
| | Type A | | 0.6 | 1.2 | 1.7 |
| | Type C | | | 0.1 | |
| Lutjanidae | *Lutjanus* sp(p). | | | 0.2 | |
| | *Rhomboplites aurorubens* | | | 0.4 | |
| Muraenidae | Unidentified | | | 0.1 | 1.3 |
| Pomacanthidae | Unidentified | | | 0.2 | |
| Pomacentridae | Unidentified | | | 0.1 | |
| Scaridae | Unidentified | | | 0.1 | |
| Serranidae | *Diplectrum formosum* | | 0.5 | 0.2 | |
| November | | + | + | + | |
| Apogonidae | Unidentified | | | 0.9 | |
| Gobiidae | *Ioglossus calliurus* | | | 0.2 | |
| | Type A | | 4.2 | | |
| Pomacanthidae | Unidentified | | | 0.2 | |
| Scaridae | Unidentified | | | 0.6 | |
| Serranidae | Unidentified | | | 0.5 | |

**Appendix Table 3**

The density (number/5-mm tow) of reef fish larvae by month and station collected in neuston tows at live-bottom sites in Onslow Bay, North Carolina. A plus sign (+) following the month indicates samples were taken during that period. Larvae from pelagic species are excluded.

| | | Station | | | |
|---|---|---|---|---|---|
| Family | Taxon | 1 | 2 | 3 | 4 |
| February | | + | + | + | |
| Sparidae | *Pagrus pagrus* | | | 0.5 | |
| May | | + | + | + | + |
| Balistidae | *Aluterus* sp. | | 0.3 | | |
| | *Monacanthus hispidus* | 3.0 | 4.0 | 0.8 | |
| | *Monacanthus* sp. | | | 0.3 | |
| Carangidae | *Seriola* sp(p). | | | 0.7 | |
| Labridae | Unidentified | | | 0.3 | |
| Mullidae | Unidentified | | 0.3 | 0.8 | |
| Sparidae | Unidentified | | | 1.0 | |
| June | | + | + | + | + |
| Balistidae | *Aluterus* sp. | | | | 1.0 |
| | *Monacanthus hispidus* | | 0.5 | 6.5 | 2.0 |
| | Unidentified | | 1.0 | 1.3 | |
| Blenniidae | *Parablennius marmoreus* | | 17.0 | | |
| Carangidae | *Seriola* sp(p). | | | 0.5 | 3.0 |
| Mullidae | Unidentified | | 0.2 | 3.0 | |
| July | | + | + | + | |
| Balistidae | *Monacanthus hispidus* | | | 3.0 | |
| Mullidae | Unidentified | | | 15.0 | |
| August | | + | + | + | |
| Balistidae | *Aluterus shoepfi* | | 1.0 | | |
| | *Aluterus scriptus* | | | 0.2 | |
| | *Monacanthus hispidus* | 2.5 | 3.5 | | |
| | *Monacanthus* sp(p). | | | 0.3 | |
| Carangidae | *Seriola* sp(p). | | 1.5 | | |
| Mullidae | Unidentified | | 0.5 | | |
| Serranidae | *Liopropoma* sp. | | | 0.2 | |
| September | | + | + | + | + |
| Balistidae | *Aluterus shoepfi* | | 0.2 | | |
| | *Aluterus* sp. | | | 0.2 | |
| | *Balistes capriscus* | | 0.2 | | |
| | *Monacanthus ciliatus* | | 0.5 | | |
| | *Monacanthus hispidus* | 1.0 | 37.2 | 4.0 | |
| Carangidae | *Seriola* sp. | | | 0.2 | |
| Gobiidae | *Ioglossus calliurus* | | | 0.2 | |
| Pomacentridae | *Abudefduf saxatilis* | | 0.2 | | |
| October | | + | + | + | + |
| Balistidae | *Aluterus* sp. | | | 0.2 | |
| | *Monacanthus hispidus* | | 7.7 | | |
| Blenniidae | *Parablennius marmoreus* | | 8.0 | 0.2 | |
| Gobiidae | *Ioglossus calliurus* | | | 0.7 | 1.0 |
| | Type A | | 0.3 | 0.5 | 1.0 |
| | Type C | | 0.7 | | |
| Ophichthidae | *Apterichtus ansp* | | | 0.2 | |
| Scaridae | Unidentified | | | 0.2 | |
| Serranidae | *Diplectrum formosum* | | | 0.2 | |
| November | | + | + | + | |
| Balistidae | *Monacanthus hispidus* | | 0.5 | 0.5 | |
| | *Monacanthus* sp. | | 0.5 | | |
| Mullidae | Unidentified | | | 2.0 | |