THE OCCURRENCE OF SPOT, *LEIOSTOMUS XANTHURUS*, AND ATLANTIC CROAKER, *MICROPOGONIAS UNDULATUS*, LARVAE IN ONSLOW BAY AND NEWPORT RIVER ESTUARY, NORTH CAROLINA[1]

Past studies indicate that spot, *Leiostomus xanthurus*, and Atlantic croaker, *Micropogonias undulatus*, spawn offshore in autumn and probably in winter (Hildebrand and Schroeder 1928; Hildebrand and Cable 1930; Dawson 1958). Peak spawning times and specific spawning areas have been deduced from sightings of large numbers of recently spawned larvae at specific locations nearshore or offshore. Weinstein et al. (1980) reported on the upstream distribution of postlarval spot and Atlantic croaker within the Cape Fear River estuary, N.C., above a steam electric power plant.

Extensive studies have been conducted in the Cape Fear River estuary[2] in the southern portion of Onslow Bay. Some of these studies dealt with recruitment of sciaenids into the Cape Fear River estuary. However, the hydrographic conditions of this estuary[3] are markedly different from those of other estuaries along the North Carolina coast and from most other estuaries along the east coast of the United States; therefore, any comparisons made with the Cape Fear findings will result in some differences.

In our current study which extended from October 1972 through April 1974, ichthyoplankton was systematically sampled monthly in northern Onslow Bay and Newport River estuary, N.C. The goal of the study was to determine the abundance and distribution of Atlantic menhaden, *Brevoortia tyrannus*, larvae (Nelson[4]), but spot and Atlantic croaker larvae were also caught in large numbers. Our study is based on the findings from these sciaenid samples. We present data on the occurrence, size, and abundance of spot and Atlantic croaker larvae from offshore to inshore and relate these findings to spawning time and area, as well as timing and duration of recruitment of these larvae into the Newport River estuary. Little has been previously published concerning the recruitment of larvae of these two species into estuaries, particularly in North Carolina waters.

Methods

Larval fish were collected monthly aboard the RV *Onslow Bay* by towing paired 60 cm bongo plankton nets of 0.333 and 0.505 mm mesh. Oblique tows were conducted from surface to near bottom at each station at a speed of 2.8 km/h (1.5 kn). Minimum duration of tows was 5 min, and the number of oblique tows (normally 2-4) made at each station depended on the water depth. This procedure was followed to insure similarity of water volumes sampled at each station. Bongo nets were weighted with a 45.4 kg (100-lb) lead weight, and depth of tow was recorded with a bathykymograph attached just above the bongo nets. Flow rates were estimated from torpedo-shaped digital flowmeters (made by General Oceanics, Inc., Miami, Fla.[5]) that were placed in the center of the mouth of each bongo net. A calibration factor, based on the length of tow, was determined for each flowmeter; average volume of water strained, per station per month, ranged from 63.3 to 78.1 m^3.

Collection stations were grouped among three areas: Offshore, inshore, and estuarine. The two ocean areas were each divided into three zones, while the estuarine area was considered one zone (Fig. 1). The approximate distances from shore, depths of water, and number of stations for each zone are described in Table 1.

The number and location of stations varied between the 1972-73 and the 1973-74 sampling periods. Nineteen stations were sampled each month, except April, from October 1972 to September 1973. In October 1973, three inshore stations, two in zone 1 and one in zone 2, and all offshore stations in zone 4 were deleted, and three stations in zone 6 were added,

[5]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

TABLE 1.—Number, offshore distance, and depth of collection stations in Zones 0-6, Onslow Bay and Newport River estuary, N. C., 1972-73 and 1973-74.

Area	Zone no.	No. stations 1972-73	No. stations 1973-74	Distance offshore (km)	Depth (m)
Offshore	6	0	3	74-79	32.9-40.2
	5	3	3	44-50	27.4-31.1
	4	3	0	32-36	21.9-27.4
Inshore	3	3	3	17-22	16.5-20.1
	2	3	2	8-13	14.6-16.5
	1	3	1	3-6	14.6-14.6
Newport River estuary	0	4	4	0	1.8-12.8

[1]Contribution No. 83-20B, Southeast Fisheries Center Beaufort Laboratory, National Marine Fisheries Service, NOAA, Beaufort, NC 28516.
[2]Brunswick Steam Electric Plant, Cape Fear Studies, Sections 1-10. Reports to Carolina Power and Light Co., Raleigh, N.C., January 1980, 428 p.
[3]Brunswick Steam Electric Plant, Cape Fear Studies. Ocean larval fish, November 1976-1978. Environmental Technology Section, Vol. V, 1979. Report to Carolina Power and Light Co., Raleigh, N.C., 305 p.
[4]Nelson, W. R. 1977. Onslow Bay studies. Unpubl. manuscr., 64 p. Southeast Fisheries Center Beaufort Laboratory, National Marine Fisheries Service, NOAA, Beaufort, N.C.

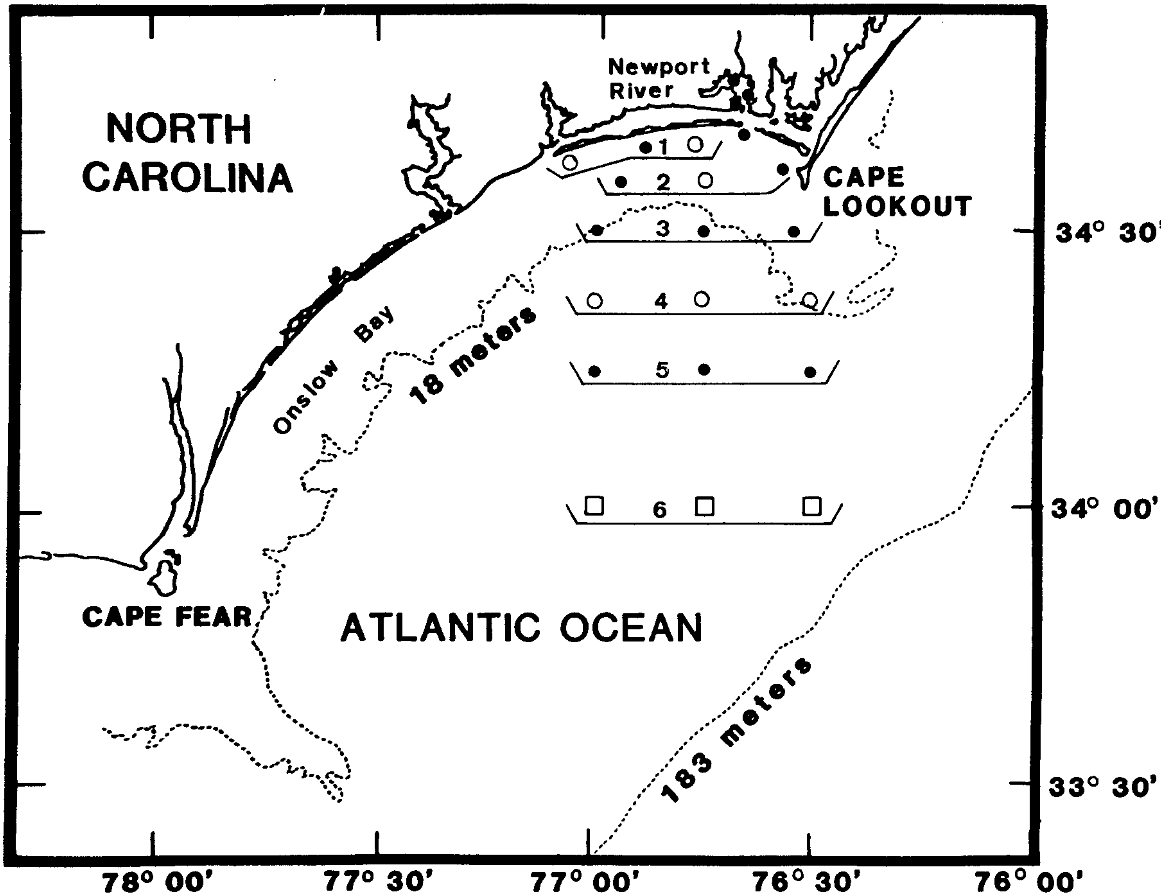

FIGURE 1.—Location of ichthyoplankton stations in Onslow Bay and Newport River estuary, N.C., sampled October 1972-April 1974 (dots), October 1972-September 1973 (circles), and October 1973-April 1974 (squares). Sampling stations are grouped according to offshore distance and water depth: Zone 0, Newport River estuary; zones 1-3, inshore to ocean; zones 4-6, offshore to ocean.

leaving 16 stations to be sampled the second year. Because the *Onslow Bay* had limited range and had to be returned to port each night, about 5 d/mo were required to run all stations. Samples were taken between 0800 and 1700 h. Tows were not stratified by tidal cycle; all collections were assumed completely random. During the 19 mo, sampling was missed completely for 1 mo and was only partially completed during six other months, due either to mechanical failure of the vessel or winch or to adverse weather.

Samples were preserved in 5% buffered Formalin. Larvae and eggs were removed with the aid of a dissecting microscope. Larvae were identified to the lowest determinable taxon, counted, and measured to the nearest 0.1 mm standard length (SL) or notochord length, depending on stage of development. All measurements denote larval length. For large catches, 50 larvae/subsample were measured. Larvae were categorized by length groups according to the developmental stages as defined by Fruge and Truesdale (1978) and Powell and Gordy (1980). Preflexion larvae measured 2.0-4.0 mm SL, flexion 4.1-5.0 mm, and postflexion >5.0 mm. Larval data from the 0.333 and 0.505 mm mesh nets were combined for each station within a month to provide a better synoptic profile of each station, since there is less extrusion of larvae <4 mm from the 0.333 mm mesh net and higher catches of larvae >10 mm in the 0.505 mm mesh net. Counts were adjusted to a standard catch (Smith and Richardson 1977:36) at each station by the following formula:

$$\mathrm{SHF} = \frac{100\mathrm{D}}{\mathrm{V}}$$

where SHF = standard haul factor
V = volume of water strained (m^3)

D = depth of sample (m)
100 = number of square meters of surface area.

For example, a tow which strains 60 m^3 of water through a depth of 12 m provides a SHF of 20. Multiplying the number of larvae in the catch by the SHF gives an estimate of the number of larvae in the entire water column under a surface area of 100 m^2. Thus the calculated number is dependent on both density (number per m^3) and depth.

Results

We compared mean standard lengths and larval abundance for each species by month, station, and year to show spawning time and movement.

Spot, 1972-73 Season

Limited spawning may have occurred in September, since only one spot larva was caught in October, when sampling began (Table 2). A few larvae were caught at three offshore and two inshore stations in November and at all offshore and four inshore stations in December. Preflexion larvae (2.0-4.0 mm), which denote recent spawning and were present at all of those stations, increased markedly in abundance in December, especially at offshore stations. Mean length of larvae increased from November to December by about 1 mm at offshore stations, but decreased by slightly <1 mm at inshore stations. No larvae were captured at estuarine stations until January. In January, larvae were caught at all offshore, five inshore, and three estuarine stations. Preflexion larvae were caught at two offshore stations, but none were caught at inshore stations. This was the last month that preflexion larvae were present, indicating that spawning had ceased or at least diminished. Mean lengths were 7.9 mm at offshore and 9.2 mm at inshore stations, an increase over December of 4.4 and 5.8 mm, respectively. This was the largest increase recorded and reflects the decline of preflexion larvae at offshore stations and their absence at inshore stations. Mean length of larvae caught at estuarine stations was 13.3 mm. In February, as in the previous 2 mo, larvae were caught in relatively large numbers at all offshore stations, but in relatively low numbers at inshore stations. The number of larvae in the estuary during February increased fivefold over those caught in January. Larval mean lengths had increased only slightly in each area (offshore, inshore, and estuarine). In March, larvae were caught at one offshore, seven inshore, and three estuarine stations. Fewer larvae were caught in March than in February, but mean lengths had increased in each area.

From October through March, an average of 28.2 and 2.2 spot larvae/station sampled were caught offshore and inshore, respectively. Number of larvae per station peaked at offshore (81.7) and inshore (4.3) stations in December and at estuarine stations (367.0) in February. Mean lengths of larvae from offshore to inshore increased in November (no larvae were caught in the estuary) and progressively increased from offshore to the estuary during January-March. The large number and relatively small size of larvae caught offshore, as compared with the number

TABLE 2.—Number of sampling stations, and number and length of spot larvae collected in Onslow Bay and Newport River estuary, N.C., October-March 1972-73 and 1973-74.

		1972-73				1973-74			
		No.	Total	Length (mm SL)		No.	Total	Length (mm SL)	
Month	Area	stn.	larvae	Range	Mean	stn.	larvae	Range	Mean
October	Offshore	4	0	—	—	0	0	—	—
	Inshore	7	1	4.4	4.4	6	0	—	—
	Estuary	4	0	—	—	4	0	—	—
November	Offshore	6	15	2.6-3.0	2.8	6	1	7.6	7.6
	Inshore	9	3	3.2-4.2	3.8	6	5	2.0-3.2	2.5
	Estuary	4	0	—	—	4	0	—	—
December	Offshore	6	490	2.4-5.6	3.5	2	17	2.7-4.6	3.4
	Inshore	9	39	2.6-5.2	3.4	6	15	3.0-6.6	4.8
	Estuary	4	0	—	—	4	0	—	—
January	Offshore	6	252	2.4-12.0	7.9	6	554	2.4-9.6	5.0
	Inshore	9	7	4.4-11.2	9.2	6	40	3.6-13.2	9.4
	Estuary	4	310	11.2-16.4	13.3	4	6	11.6-16.0	13.3
February	Offshore	6	198	4.4-12.8	8.3	3	3	3.3-7.4	5.5
	Inshore	9	31	5.2-12.8	9.5	6	5	7.2-11.7	8.9
	Estuary	4	1,468	8.8-18.8	13.7	3	2	12.9-14.6	13.8
March	Offshore	6	5	6.4-12.0	9.0	3	1	7.2	7.2
	Inshore	9	31	7.6-16.0	13.4	6	1	10.8	10.8
	Estuary	4	84	10.4-18.0	14.5	4	2	12.0-14.8	13.4
Totals	Offshore	34	960			20	576		
	Inshore	52	112			36	56		
	Estuary	24	1,862			23	10		

and length of those caught inshore, indicated that more spawning occurs offshore than inshore.

Spot, 1973-74 Season

Although samples were taken from May 1973 through April 1974, not all stations were sampled each month, and no spot larvae were caught until November. In November, one larva (7.6 mm) was caught at an offshore station, none were caught at estuarine stations, and only five (all preflexion larvae, 2.0-4.0 mm) were caught at inshore stations (Table 2). The presence of preflexion larvae indicated that spot had spawned recently, and the presence of the postflexion larva (7.6 mm) denoted that some spot had spawned as early as October. However, low abundance of larvae in October samples, taken over two spawning seasons, indicated only limited early-season spawning. In December, larvae were caught at the only two offshore stations sampled and at four inshore stations, but none were caught at any estuarine stations. Preflexion larvae were caught at both offshore stations and at one inshore station. In January, more spot larvae were caught in each of the three sampling areas than at any other time of the current season. Larvae were caught at all offshore and four inshore stations. Preflexion larvae, captured at five offshore stations and one inshore station, indicated that spot had recently spawned and that spawning was widespread within and probably outside the sampling area. Other larvae ranged up to 9.5 mm offshore and up to 13.2 mm inshore. A few larvae, ranging from 11.6 to 16.0 mm, were caught at estuarine stations. In February, the number of larvae showed a marked decline; only three were caught at offshore, five at inshore, and two at estuarine stations. Preflexion larvae were caught at one offshore station. The remaining larvae ranged from 7.2 to 11.7 mm at other offshore and inshore stations. Larvae caught at estuarine stations measured 12.9 and 14.6 mm. In March, only four larvae were caught, all postflexion, ranging from 7.2 mm at offshore stations to 14.8 mm at estuarine stations. In April, one 4 mm larva was caught at an offshore station, and none were caught at inshore or estuarine stations.

From October through March an average of 28.8 and 1.6 spot larvae/station sampled were caught at offshore and inshore stations, respectively. Larval abundance peaked at offshore and inshore stations in January, as compared with December of the previous season. Abundance at estuarine stations was very low; six larvae were caught in January, two in February, and two in March. In December, mean lengths increased from offshore to inshore (no larvae were caught in the estuary), and from January through March mean lengths progressively increased from offshore to the estuary. As during the 1972-73 spawning season, the large number and relatively small size of larvae caught offshore, compared with those caught inshore, indicated that more spawning occurs offshore than inshore.

Atlantic Croaker, 1972-73 Season

No samples were taken prior to October 1972, but number and size of larvae collected in October indicated that Atlantic croaker had spawned in September. In October, larvae were caught at three offshore, six inshore, and two estuarine stations (Table 3). Preflexion larvae (2.0-4.0 mm), indicative of recent spawning, were caught at three offshore stations and at five inshore stations. Larvae caught at estuarine stations ranged from 4.3 to 9.9 mm and included both flexion and postflexion larvae. These Atlantic croaker larvae were recruited into the estuary at a much smaller size and about 3 mo earlier than spot larvae. In November, Atlantic croaker larvae were caught at all offshore and inshore stations, but were not caught at any estuarine stations. The presence of preflexion larvae, caught at five offshore and five inshore stations, indicated that spawning was widespread within and probably outside our sampling area. In December, larvae were caught at all offshore and four inshore stations. Preflexion larvae continued to be quite abundant and occurred at three offshore and four inshore stations. Only postflexion larvae were caught at estuarine stations. Preflexion larvae were not caught after December, indicating that spawning had probably ended or at least diminished. In January, larval abundance declined in each area, but larvae were caught at all offshore, three inshore, and two estuarine stations. In February, larval abundance increased slightly at offshore and inshore stations and showed a marked increase at estuarine stations. Larvae were caught at four offshore, three inshore, and all estuarine stations. In March, mean length and number of larvae caught in each area declined from the previous month. Larvae were caught at two offshore, four inshore, and three estuarine stations. No samples were taken in April, and no larvae were caught after March.

From October through March, an average of 10.6 and 5.0 Atlantic croaker larvae/station sampled were caught offshore and inshore, respectively. Abundance peaked at offshore stations in November (1 mo earlier than spot larvae), at inshore stations in December (same as spot), and at estuarine stations in Feb-

TABLE 3.—Number of sampling stations, and number and length of Atlantic croaker larvae collected in Onslow Bay and Newport River estuary, N.C., October-March 1972-73 and 1973-74.

		1972-73				1973-74			
		No.	Total	Length (mm SL)		No.	Total	Length (mm SL)	
Month	Area	stn.	larvae	Range	Mean	stn.	larvae	Range	Mean
October	Offshore	4	41	2.3-6.5	4.1	0	0	—	—
	Inshore	7	61	2.6-8.2	4.4	6	25	2.4-8.0	5.1
	Estuary	4	84	4.3-9.9	7.1	4	15	4.4-8.0	5.8
November	Offshore	6	211	2.2-10.6	3.5	6	1	3.0	3.0
	Inshore	9	62	2.2-11.6	5.0	6	21	2.4-7.6	3.8
	Estuary	4	0	—	—	4	3	7.2-9.6	8.3
December	Offshore	6	60	3.0-7.7	5.4	2	0	—	—
	Inshore	9	104	2.8-9.0	5.5	6	13	4.8-10.0	7.3
	Estuary	4	25	8.8-11.6	10.0	4	9	9.4-11.8	10.5
January	Offshore	6	13	4.8-9.0	7.3	6	6	4.0-5.6	4.7
	Inshore	9	4	8.0-10.4	9.4	6	5	8.4-10.0	9.2
	Estuary	4	10	10.0-12.8	10.9	4	0	—	—
February	Offshore	6	31	4.8-10.4	7.8	3	0	—	—
	Inshore	9	16	7.6-11.6	9.2	6	0	—	—
	Estuary	4	440	7.6-22.8	10.5	3	31	9.0-12.9	11.2
March	Offshore	6	3	5.2- 7.2	6.1	3	0	—	—
	Inshore	9	12	7.6-10.0	8.6	6	0	—	—
	Estuary	4	25	7.2-12.0	10.1	4	8	9.6-12.0	10.8
Totals	Offshore	34	359			20	7		
	Inshore	52	259			36	64		
	Estuary	24	584			23	66		

ruary (same as spot). In November, mean length increased from offshore to inshore (no larvae were caught in the estuary). During each of the other months, mean lengths progressively increased from offshore to the estuary. Larval distribution and size indicated a greater frequency of spawning closer to shore by Atlantic croaker than by spot. Also, the Atlantic croaker larvae were recruited into the estuary earlier in the season and at a smaller size than were spot larvae.

Atlantic Croaker, 1973-74 Season

Samples were taken from May 1973 through April 1974, but not all stations were sampled each month (Table 3). Eight Atlantic croaker larvae, ranging in length from 3.3 to 5.2 mm, were caught at estuarine stations in September and were the smallest caught in the estuary (not included in Table 2). In October, no samples were taken at offshore stations but larvae were caught at four inshore and two estuarine stations. Preflexion larvae (2.0-4.0 mm), which denote recent spawning, were caught at one inshore station. Larvae caught at estuarine stations were either flexion (4.1-5.0 mm) or postflexion (>5.0 mm). In November, larvae were caught at one offshore, four inshore, and two estuarine stations. Preflexion larvae were caught at one offshore and three inshore stations. This was the last month that preflexion larvae were present, except for one caught in January. Larvae caught in the estuary were all postflexion. In December, no Atlantic croaker larvae were caught at offshore stations, but they were caught at four inshore stations and at two estuarine stations. Size ranged from 4.8 mm inshore to 11.8 mm in the estuary. In January, larvae were caught at three offshore and two inshore stations, but none were caught at any estuarine stations. Larvae caught offshore ranged from 4.0 to 5.6 mm, indicating that spawning had probably occurred between our December and January collections. Larvae caught inshore were all postflexion. In February and March, larvae were not caught at any offshore and inshore stations, but were caught at two estuarine stations in February and three in March. All larvae were postflexion. In April, two offshore, seven inshore, and four estuarine stations were sampled, but only one larva was caught, a 6.0 mm larva at an inshore station.

Certain similarities were noted between the 1972-73 and 1973-74 spawning seasons, even though only a limited number of Atlantic croaker larvae were caught during the latter period, and not enough were caught during any month to determine the time of peak abundance. From October through March, an average of only 0.4 and 1.9 mm larvae/station sampled were caught offshore and inshore, respectively. When larvae were caught in each of the three areas, mean lengths progressively increased from offshore to the estuary. When larvae were caught in only two areas, mean length increased either from offshore to inshore or from inshore to the estuary. Distribution and size of larvae indicated a greater frequency of spawning closer to shore by the Atlantic croaker than by spot, as with larvae caught during 1972-73. Also, as in 1972-73, Atlantic croaker larvae were recruited into the estuary earlier in the season and at a smaller size than were spot larvae.

Discussion

The distribution and abundance of sciaenid larvae differed between the two spawning seasons studied. The estimated numbers of spot and Atlantic croaker larvae present at selected stations (those that were sampled each month and could be compared between the two years) in each of the three sampling areas indicated that during the 1973-74 season the numbers of spot and Atlantic croaker larvae were 34 and 87% less, respectively, than during the previous year, and that the combined number of larvae for both species was down 55%. This decline could have resulted from a higher mortality of eggs or early-stage larvae, from stations being missed (other than selected stations), from peaks of abundance being missed, or from a true decline in numbers present.

Nelson et al. (1978) found that inshore and offshore Ekman transport mechanisms affected the abundance of Atlantic menhaden larvae in the surface waters of Onslow Bay. Since no comparable studies[6] have been conducted for spot and Atlantic croaker larvae in these offshore areas, we must infer movement and drift patterns of these species from studies within the estuaries, and by relating egg and larval stages to their likely position in the water column as they move from offshore towards an inlet.

Eggs and preflexion sciaenid larvae are buoyant and would be near the surface waters where they would respond to the forces of Ekman transport; however, larvae probably become demersal during the flexion and postflexion stages. As this "settling out" phenomenon occurs, they would be less affected by the Ekman transport of surface waters and more affected by other forces (inertia and Coriolis) that occur at greater depths.

Within the estuary, young spot and Atlantic croaker larvae are abundant in the middle and lower layers of the water column during the day, while at night they tend to accumulate near the surface (Wallace 1941; Haven 1957; Lewis and Wilkens 1971; Weinstein et al. 1980). Most sciaenid larvae, except for the earlier stages, are probably within these layers in Onslow Bay. Stefánsson et al. (1971) found that the circulation pattern of water in Onslow Bay was progressively changing seasonally, but that there was always an indication of a general counterclockwise eddy. Unpublished field and experimental observations at the Southeast Fisheries Center Beaufort Laboratory of the National Marine Fisheries Service indicate that small sciaenid larvae are able to swim against the current for brief periods of time. Sciaenid larvae probably are able to move into the estuaries from offshore by a combination of swimming, resting on or near the bottom, and drifting with the current or water mass.

Even though spot and Atlantic croaker larvae were taken over the same general time period each year, some differences between the two species occurred in spawning time, movement, abundance, and larval size. Atlantic croaker spawned before October of each year, since larvae were captured in relatively large numbers in the ocean in October, about 2 mo earlier than spot larvae (Tables 2, 3). Atlantic croaker larvae were first captured in the estuary in either September or October of each year, whereas no spot larva was caught in the estuary until January, about 4 mo later than the Atlantic croaker.

Atlantic croaker larvae caught in October and November at offshore and inshore stations were generally larger than spot larvae caught in November and December (Tables 2, 3). This larger size, however, was not maintained. After the initial 2 mo, mean lengths of the Atlantic croaker were usually less than those of spot in comparable time periods and sampling areas. Also, Atlantic croaker larvae caught in inside waters were noticeably smaller than spot larvae. This size difference between the two species, and the fact that Atlantic croaker larvae were captured in the estuary much earlier in the season than spot, indicate that Atlantic croaker spawn earlier in the season and/or closer to shore than spot, and that their larvae usually move into the estuary at a smaller size and probably at an earlier age. Warlen (1982) and Warlen and Chester[7] generally agreed that larval size and age are related. However, during winter months with water temperatures relatively low, they found more age variations in larvae of similar lengths than with water temperatures relatively high.

Hildebrand and Cable (1930) believed that spot and Atlantic croaker spawned relatively nearshore in the Beaufort, N.C., area and that the principal spawning months were December-January for spot and October-March for Atlantic croaker. Powles and Stender (1978) reported that spot and Atlantic croaker spawn over the continental shelf in the South Atlantic Bight. We found that spot spawn more heavily offshore than inshore, whereas Atlantic croaker spawn with about equal intensity in both

[6]Cape Fear River Estuary studies in southern Onslow Bay were done under different hydrographic conditions than we encountered in the current study.

[7]Warlen, S. M., and A. J. Chester. 1982. Age, growth and distribution of larval/early juvenile spot, *Leiostomus xanthurus*, off North Carolina. Unpubl. manuscr., 25 p. Southeast Fisheries Center Beaufort Laboratory, National Marine Fisheries Service, NOAA, Beaufort, N.C.

areas. Although spawning occurs over several months for both species, the principal spawning months are December-January for spot and October-December for Atlantic croaker. Some Atlantic croaker were collected each month until mid-April; spot were caught through March.

Preflexion larvae, indicative of recent spawning, were present generally during the first half of each season at many offshore stations and at a lesser number of inshore stations, but the size variation of larvae between the two areas suggests that the primary spawning area was offshore (Figs. 2, 3). The 1972-73 data show that small, recently hatched larvae were more predominant offshore than inshore and that larvae generally were progressively larger as they moved into the estuary, as was also found by Warlen (1982). Size increased with passage of time as the larvae moved from the major offshore spawning area, through the transitory inshore area, to the estuarine nursery area.

With some exceptions, larvae were more abundant offshore than inshore. During the 1972-73 season, as larvae moved to inshore waters, their numbers (available to our gear) usually showed a marked decline, probably the result of natural mortality, predation, and the ability to avoid capture because of their increased mobility at a larger size. In the estuary, availability again increased as numbers built up in a much smaller area (Table 4).

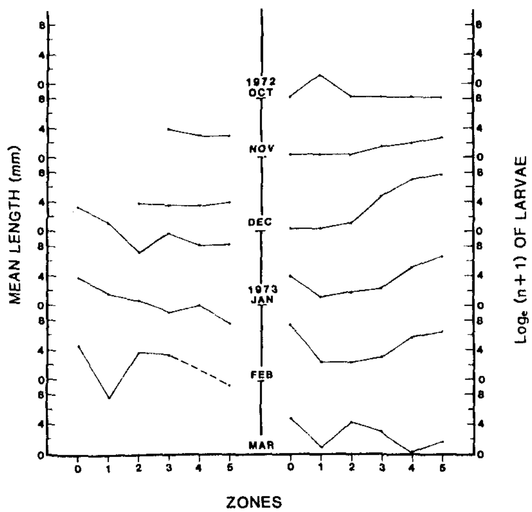

FIGURE 2.—Mean length and relative abundance of spot larvae collected October 1972-March 1973 in Onslow Bay and Newport River estuary, N.C. Sampling stations are grouped according to offshore distance and water depth: Zone 0, Newport River estuary; zones 1-3, inshore to ocean; zones 4-6, offshore to ocean. The mean length (mm) scale is 0-10 for each month. Some plots extend into adjacent months when a point exceeds 10 mm (i.e., the first point plotted in February is 14 mm).

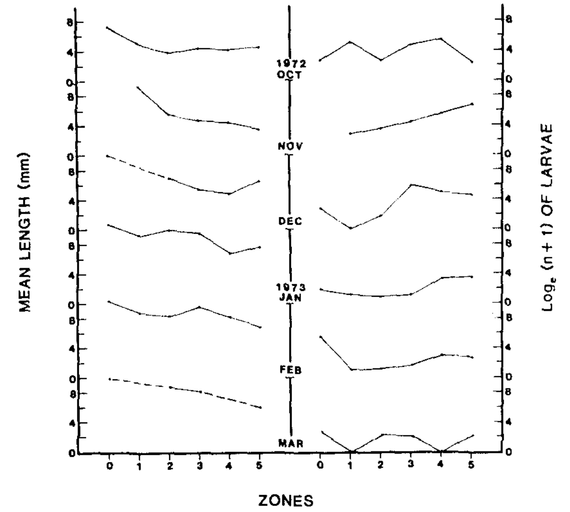

FIGURE 3.—Mean length and relative abundance of Atlantic croaker larvae collected October 1972-March 1973 in Onslow Bay and Newport River estuary, N.C. Sampling stations are grouped according to offshore distance and water depth: Zone 0, Newport River estuary; zones 1-3, inshore to ocean; zones 4-6, offshore to ocean. Some plots extend into adjacent months as in Figure 2.

TABLE 4.—Estimated numbers and percentages of spot and croaker larvae (adjusted by standard haul factor) collected in Onslow Bay and Newport River estuary, N.C., October-April 1972-73 and 1973-74.

Area and species	1972-73			1973-74		
	No. larvae	No./stn	% by area	No. larvae	No./stn	% by area
Offshore						
Spot	16,436	483	55.5	10,812	491	93.5
Croaker	5,398	159	43.1	111	5	8.8
Total	21,834	642	51.8	10,923	496	85.1
Inshore						
Spot	1,206	23	4.1	681	16	5.9
Croaker	2,822	54	22.6	665	16	52.6
Total	4,028	77	9.6	1,346	32	10.5
Estuary						
Spot	11,954	498	40.4	74	3	0.6
Croaker	4,294	179	34.3	488	18	38.6
Total	16,243	677	38.6	562	21	4.4
Totals						
Spot	29,596	269		11,567	127	
Croaker	12,514	114		1,264	14	
Total	42,110	383		12,831	141	

We were unable to relate the mean length and relative abundance of spot and Atlantic croaker larvae to different sampling areas for the 1973-74 season, to the same degree as for the 1972-73 season, because of the low availability of larvae.

The conclusions derived from our Onslow Bay study show a general offshore-to-inshore gradient for spot and Atlantic croaker larvae. This gradient for both mean numbers and size of larvae appears to be a function of distance from shore and time of year.

Generally, protracted spawning occurs offshore, and larvae of these two species continue to grow as they move toward shore and into the estuary. Two primary factors that seem to affect growth are water temperature and the amount of plankton "blooms" present (Williams et al. 1968). Therefore, in February and March, with some exceptions, as water temperatures start to rise, collections will have larger individuals by area than during colder months. By considering a specific point along this route as larvae move from offshore areas to the estuary and then by looking at the monthly means, we note that size increases seasonally.

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SURVIVAL AND HOMING OF JUVENILE COHO SALMON, *ONCORHYNCHUS KISUTCH*, TRANSPORTED BY BARGE

During the winter and spring of 1976-77 the Pacific Northwest experienced its worst drought in recent times. Flow in the Columbia River, which is dammed extensively for hydroelectric generation and irrigation, was extremely low during the spring of 1977 (averaging $<4,245$ m^3/s). In low flow years, very little water is diverted over spillways at the hydroelectric projects. Consequently, many migrating juvenile Pacific salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdneri*, were destined in 1977 to pass through the turbines, where substantial numbers would be killed (Chaney and Perry 1976[1]) unless remedial steps were taken. Realizing that the losses of juvenile salmonids could be catastrophic, the National Marine Fisheries Service (NMFS) and the U.S. Army Corps of Engineers (CofE) prepared two barges to supplement trucking as a means of transporting juvenile salmonids around dams on the Columbia and Snake Rivers (McCabe et al. 1979).

To assess the effectiveness of barging, various experiments were conducted. One, a joint activity by NMFS, the U.S. Fish and Wildlife Service (FWS), and CofE, involved transporting tagged coho salmon, *Oncorhynchus kisutch*, from Willard National Fish Hatchery (Little White Salmon River), Wash., to a release site on the Columbia River downstream from Bonneville Dam (Fig. 1). Objectives of the experi-

[1]Chaney, E., and L. E. Perry. 1976. Columbia Basin salmon and steelhead analysis: Summary report; 1 September 1976. Pac. Northwest Reg. Comm., Vancouver, Wash., 74 p.