REPRODUCTION OF THE BANDED DRUM, *LARIMUS FASCIATUS*, IN NORTH CAROLINA[1]

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ABSTRACT

The reproductive biology of *Larimus fasciatus* was examined in coastal North Carolina from September 1975 through September 1976. Spawning occurred in nearshore waters from April through September with a peak in August. Maturity in fameles was reached by the first year between 120 and 130 mm SL. Generally the larger, older fish matured earlier and also continued spawning later in the season than the younger ones.

Fecundity ranged from 12,750 to 320,819 ova with first spawners preducted to have between 31,088 and 65,038 eggs. Fecundity was best predicted by ovary weights during August. Sex ratios generally favored more females. As fish grew the sex ratio changed from predominately males to predominately females.

The banded drum, *Larimus fasciatus* Holbrook, occurs from Massachusetts to southeastern Florida and along the northern Gulf of Mexico from the Florida west coast to Mexico. Unlike other drums it appears to be largely restricted to nearshore coastal waters at all sizes and is rarely collected in estuaries or from the outer continental shelf (Gunter 1938; Dahlberg 1972; Chao 1978; Powles 1980). *Larimus fasciatus* is a small sciaenid reported by Holbrook (1860) to reach 305 mm TL (total length), but it seldom grows larger than 220 mm (Chao 1978). Its small size, low abundance, and lack of status as a food or game fish afford this species little commercial or recreational value, although it was reported as a component of the North Carolina (Wolff 1972) and Gulf of Mexico (Gutherz et al. 1975) industrial fisheries.

Published data on life history aspects of *L. fasciatus* are largely lacking. Hildebrand and Cable (1934) reported limited information on spawning, growth, and juvenile descriptions of North Carolina specimens, and Powles (1980) presented data on larval description, spawning seasons, and areas in the South Atlantic Bight. Feeding habits were briefly examined by Welsh and Breder (1923) and Chao and Musick (1977). Standard and Chittenden (in press) have studied banded drum life history off of Texas.

This study describes the following aspects of *L. fasciatus* life history in North Carolina: 1) spawning seasonality, 2) age and size at maturity, 3) fecundity, and 4) sex ratios.

METHODS

Most banded drum were collected in the ocean near the mouth of the Cape Fear River, N.C., about 4-6 km off Oak Island in depths of 4-14 m (Fig. 1). Bottom topography was uniform with sediments of fine sand and mud. Hydrographic conditions were heavily influenced by discharge from the Cape Fear River (Ross 1978).

This area was sampled weekly from September 1975 through September 1976, except only monthly samples were made during January, June, July, and August. Each sample consisted of repetitive (4-12) 30-min trawls with a 12.4 m semiballoon otter trawl of 3.85 cm stretched mesh during daylight hours.

Additional specimens were collected from September 1975 through September 1976 during twice monthly, daylight sampling between Beaufort Inlet and Cape Lookout, N.C. (Fig. 1), except that there was no sampling in December 1975 and only monthly sampling in January and February 1976. Repetitive trawls were made in this area in a depth range of 9-12 m over a flat, sand bottom using the aforementioned gear and tow times. Specimens were also collected near Cape Hatteras (9-17 m depth) in November and December 1975 and April 1976 by the North Carolina Division of Marine Fisheries (Fig. 1).

Larimus fasciatus were preserved in the field in 10% Formalin[3] and later stored in 40% isopropanol. Total length (TL) and standard length (SL) were measured to the nearest mm. Body weights (BW) were determined to the nearest 0.1 g, and gonads $\geq$0.01 g were

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

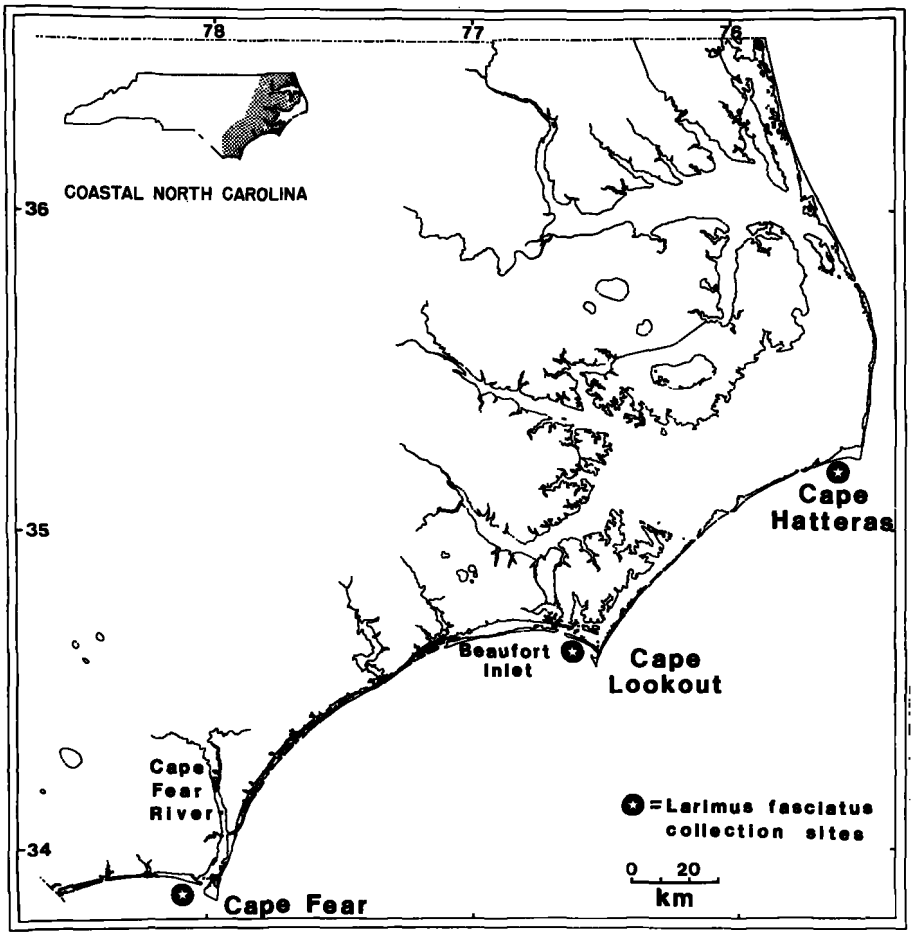

FIGURE 1.—Collection sites for *Larimus fasciatus* in North Carolina.

blotted dry and weighed (gonad weight (GW)) to the nearest 0.01 g. Gonad indices (GI) were calculated as follows:

$$GI = GW \text{ (both)} \times 100/(BW - GW)$$

and were used to determine spawning seasons and maturity.

Fecundity was determined for both maturing gonads by relating the number of eggs in a subsample to the whole gonad. Each subsample (weighed to the nearest 0.001 g), removed from the middle and both ends of each alcohol-preserved gonad, represented roughly 5% of the total gonad weight. All eggs (excluding those <0.01 mm in diameter and atretic eggs) in the subsample were counted, and the modal ovum diameter was measured to the nearest 0.05 mm. Total fecundity used in the analysis equaled the number of eggs in both gonads combined.

RESULTS

Spawning

Larimus fasciatus spawned from April through September with peak activity in August as indicated by female gonad indices ($n = 126$, Fig. 2). Male gonad indices ($n = 53$) somewhat mirrored the female pattern, but the spawning cycle was not clearly illustrated because the testes composed a small percentage of the body weight at any maturity stage in all months (Fig. 2). Some running ripe males were observed in the field from June through August. Since the mean gonad index was still high in September (Fig. 2), spawning may have continued after September, although I have no collections to substantiate this.

The large size range of juveniles and the collection of young-of-the-year ≤40 mm SL in all months ex-

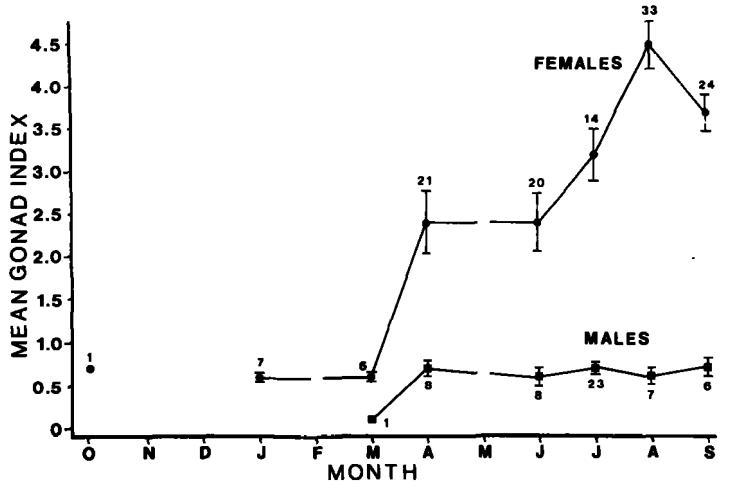

FIGURE 2.—Monthly mean gonad index of male and female banded drum from October 1975 to September 1976 in North Carolina, including sample size and ±1 standard error of the mean.

cept December 1975 and January, April, May, and June 1976 (Fig. 3) support an extended late spring through early fall spawning season. Major young-of-the-year (1976 year class) recruitment, evidently from Spring spawning, first appeared in July 1976 and continued through September 1976. Young-of-the-year from the 1975 year class were evident from September 1975 through November 1975 and appeared again in February 1976 (Fig. 3). This young-of-the-year recruitment over a long period with a lack of bimodal length frequencies indicated sustained spawning effort. Other collections in and near the lower Cape Fear River of *Larimus fasciatus* <40 mm SL in January, February, April, June, July, September, November, and December also indicated extended spawning (K. A. MacPherson[4]).

The majority of the reproductively active adults were collected near the Cape Lookout area (Fig. 1), especially during August and September where bottom water temperature averaged 27° (August) to 20°C (September). A high percentage (48.9-100%) of the total number of females collected in the Cape Lookout area exhibited maturing or ripe gonads while corresponding percentages from Cape Fear

[4]K. A. MacPherson, biologist, Carolina Power and Light Company, Brunswick Biological Laboratory, P.O. Box 10429, Southport, N.C. 28461, pers. commun. 1977.

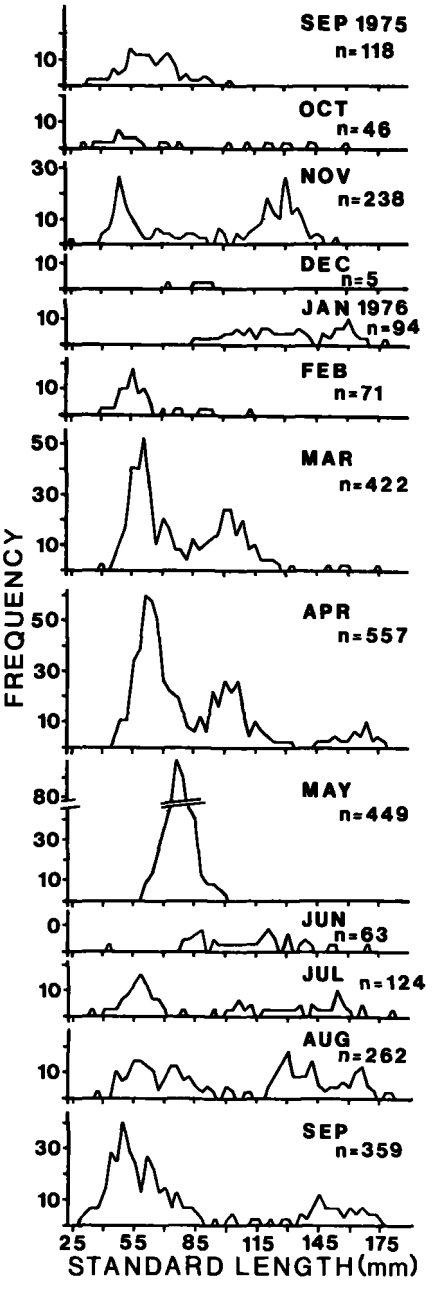

FIGURE 3.—Length frequencies of *Larimus fasciatus* collected in North Carolina from September 1975 through September 1976.

were low (0-8.1%) (Table 1). Although sampling effort in the Cape Fear area was half of that near Cape Lookout from June through August, more female banded drum were collected near Cape Fear; however, the percent of females with large gonads was much greater in the Cape Lookout area (Table 1). Cape Fear area sampling effort doubled over that near Cape Lookout in September and yielded many more female banded drum, but only 0.7% were reproductively active compared with 48.9% in the Cape Lookout area (Table 1). Irregular sampling from the Cape Hatteras area (Fig. 1) yielded maturing or ripe *L. fasciatus* only during April when 82.4% of the females collected had gonad indices between 1.7 and 6.1 (Table 1). Bottom water temperature in this area was 17°C.

Ovum diameter is often an indication of sexual maturity (Higham and Nicholson 1964), and the relationship between egg size (OD) and gonad index (GI) for banded drum ($n = 90$) was

$$OD = 0.34 + 0.11 (\ln GI), r = 0.77$$

(Fig. 4). This relationship is an objective, quantitative way to determine degree of maturity (Yuen 1955; Schaefer and Orange 1956) and was used to differentiate maturing from immature female banded drum. The point on the graph (Fig. 4) where gonad index began to increase more rapidly than egg size was used as the boundary between immature and maturing gonads and occurred around a gonad index of 1.0 and an ovum diameter of 0.35 mm. Mean ova diameters peaked from July through September at 0.48 mm (Table 2), which also coincided with the highest gonad indices.

Maturity

Female banded drum reached sexual maturity between 120 and 130 mm SL ($n = 112$). All fish ≤120 mm SL were immature (GI ≤1.0) and 97% of those ≥130 mm were mature, with 60% between 120 and 130 mm reaching maturity (Table 3). During the spawning season, females between 120 and 130 mm indicated increased gonad activity. Females smaller than 120 mm displayed no seasonal gonad activity, while only three fish ≥130 mm were not maturing during the spawning season (Fig. 5). Only the larger adults ≥150 mm matured and spawned early (April), and generally a higher proportion of the older

TABLE 1.—Percent of female *Larimus fasciatus* with gonad indices ≥1.0 and sample size (*N*) from each collection area during the spawning months of 1976.

Area	April	May	June	July	Aug.	Sept.	Total
Cape Fear	0 (274)	0 (219)	0 (9)	2.8 (36)	8.1 (111)	0.7 (153)	1.4 (802)
Cape Lookout	0 (1)	—	53.8 (26)	100 (12)	75.0 (28)	48.9 (45)	61.6 (112)
Cape Hatteras	82.4 (17)	—	—	—	—	—	82.4 (17)
Total	4.8 (292)	0 (219)	40.0 (35)	27.1 (48)	21.6 (139)	11.6 (198)	10.1 (931)

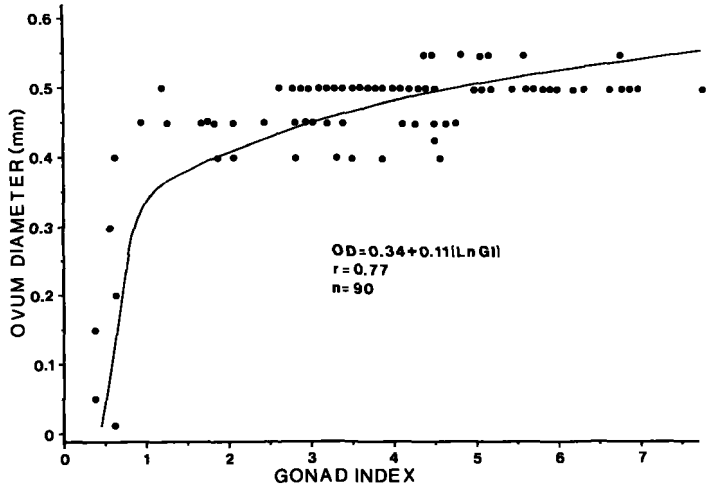

FIGURE 4.—Relationship between female gonad index and ova diameters of North Carolina *Larimus fasciatus*.

TABLE 2.—Mean monthly ova diameters of *Larimus fasciatus* from March through September 1976.

Month	Mean ova diameter (mm)	Sample size
March	0.01	1
April	0.41	7
June	0.46	16
July	0.48	13
August	0.48	32
September	0.48	21

females continued spawning later (September) (Fig. 5). Most of the smallest reproductively active females (between 120 and 130 mm SL) matured from June to August (Fig. 5).

Using age-length relationships of Ross (1978), *Larimus fasciatus* reached maturity shortly after turning 1-yr-old. They continued spawning throughout life until age 3, which was the maximum age encountered.

Fecundity

Number of ova increased with increasing fish size, ranging from 12,750 ova in a 118 mm SL female to 320,819 in a 179 mm female. The relationship between fecundity (F) and SL for 86 females was linear and expressed by the equation:

$$F = -376{,}312 + 3{,}395\ (SL),\ r = 0.76$$

(Fig. 6). Length at first spawning is between 120 and 130 mm SL and predicted fecundity in this size range is 31,088-65,038 ova. Body weight (BW) minus the gonad weight (GW) was regressed onto fecundity yielding the equation:

$$F = -52{,}741 + 1{,}887\ (BW),\ r = 0.76,\ n = 85.$$

Gonad weight varies seasonally and is closely related to fecundity; therefore, eliminating it from body weight reduced the possibility of autocorrelation. Even without the gonad weight, body weight varies seasonally and to some extent daily as a function of diet; therefore, body weight is not the best predictor of fecundity. The fecundity to ovary weight (OW)

TABLE 3.—Number and percentage of mature and immature female banded drum by 10 mm size categories off North Carolina, April-September 1976. Maturity was judged by gonad index (GI) value.

Standard length (mm)	Immature GI ≤ 1.0	Mature GI > 1.0	Percent mature
<90	1	0	0.0
90-99	0	0	0.0
100-109	4	0	0.0
110-119	4	0	0.0
120-129	6	9	60.0
130-139	1	12	92.3
140-149	1	22	95.7
150-159	0	17	100.0
160-169	1	26	96.3
170-179	0	7	100.0
180-189	0	1	100.0
Total	18	94	

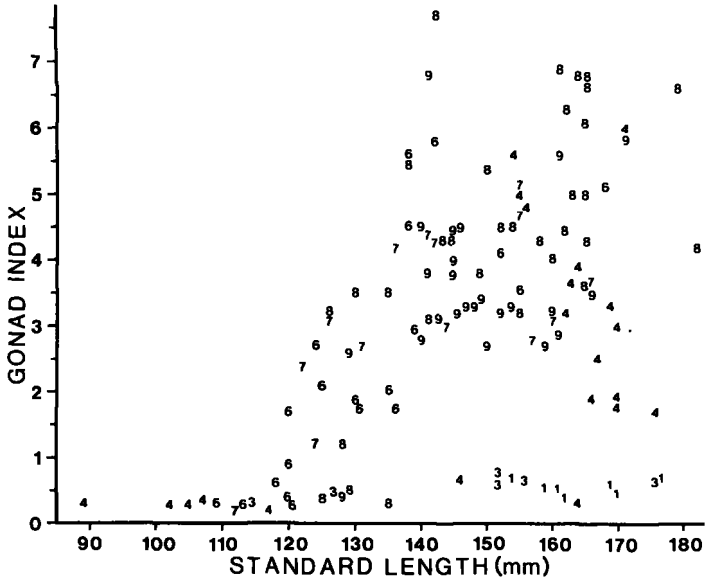

FIGURE 5.—Relationship between famale gonad index and standard length by month for banded drum during January (1)-September (9) 1976 (n = 124).

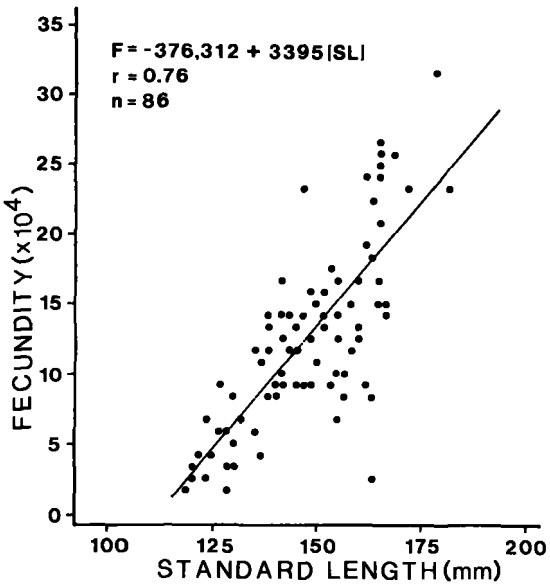

FIGURE 6.—Relationship of fecundity to standard length for banded drum collected in North Carolina from April through September 1976.

relationship was expressed by

$$F = 15{,}490 + 28{,}024\ (OW), r = 0.94, n = 85$$

and had a much higher correlation coefficient than either the length or body weight regressions. To minimize monthly variation (Morse 1980) the most accurate prediction of fecundity was derived from ovary weights only from the peak spawning month, August, expressed by

$$F = 18{,}532 + 28{,}181\ (OW), r = 0.97, n = 31$$

(Fig. 7).

Sex Ratios

Sex was determined for 2,729 banded drum and the overall ratio of males to females varied significantly from 1:1 in favor of females (Table 4). This nonhomogeneity of total sex ratios could not be accounted for by any consistent pattern of seasonal ratio differences. The two largest size groups exhibited sex ratios significantly in favor of females. The disparity between sexes in the size range 100-139 mm SL was accounted for during winter, spring, and summer, while that in the fish ≥140 mm SL was accounted for during fall and winter (Table 4). Contingency table analysis indicated strong dependency between sex and size group ($\chi^2 = 17.84$, df = 3, $P \leq 0.001$), even though differences in the smallest two size groups were nonsignificant (Table 4). As fish grew, the population shifted from more males to more females. There were more total females than males in all seasons except summer; however, the differences were only significant in the fall. The fall divergence from a 1:1 ratio was explained by differences in the 60-99 mm and ≥140 mm SL size groups (Table 4).

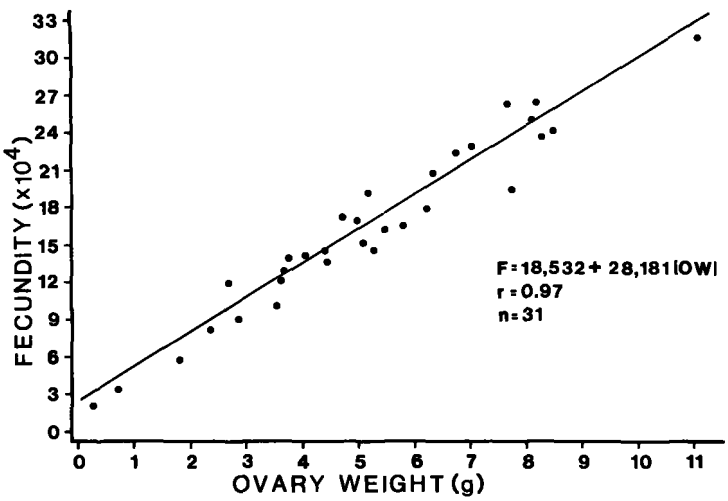

FIGURE 7.—Relationship of fecundity to overy weight during August 1976 for North Carolina banded drum.

TABLE 4.—*Larimus fasciatus* male/female sex ratios by season and size group from North Carolina (September 1975-September 1976) with chi-square values from testing a 1:1 ratio.

Size group (mm SL)	Season				Total	df	χ^2
	Fall (Sept.-Nov.)	Winter (Dec.-Feb.)	Spring (Mar.-May)	Summer (June-Aug.)			
≤59	151/144	22/27	104/100	65/34	342/305	3	5.23
60-99	77/103	15/12	492/479	65/64	649/658	3	2.14
100-139	71/67	19/34	87/123	48/74	225/298	3	8.04*
≥140	21/64	14/23	19/22	49/50	103/149	3	8.47*
Total	320/268	70/96	702/724	227/222	1,319/1,410		
df	3	3	3	3			
χ^2	9.28*	3.64	7.28	7.63	10.38*		

*$P < 0.05$.

DISCUSSION

The prolonged April-September spawning season of *L. fasciatus* in this study is supported by the few published references to its reproduction. From analysis of larval occurrence in North Carolina, Hildebrand and Cable (1934) proposed a May through October spawning season. Powles (1980) reported a May to October spawning in the South Atlantic Bight also based on larval collections. Gunter (1938) suggested April spawning for banded drum in Louisiana. Standard and Chittenden (in press) found two spawning peaks for *L. fasciatus* off Texas, a minor one in the spring (April-June) and the major one in the fall (September-November). They did not find significant evidence of spawning in July or August.

My data suggested a prolonged spawning effort in North Carolina beginning as early as April, peaking in August, and possibly continuing after September. This major departure from Standard and Chittenden's (in press) biomodel spawning was supported by 1) a steady increase in gonad indices with a single August peak, 2) a single peak mode of ova diameters of 0.48 mm from July through September, 3) continuous recruitment of young-of-the-year through the summer and fall months, and 4) the collection of larvae in all months except March (Powles 1980; K. A. MacPherson footnote 4). Although it is fairly certain that spawning begins in April, at least for larger fish, I did not determine if spawning continued into October because samples of adults were lacking. Although the September gonad index declined, young-of-the-year recruitment in North Carolina in February and larval collections in November, December, January, and February (K. A. MacPherson footnote 4) indicated that spawning may last at least through October. Protracted spawning is also characteristic of many other Sciaenidae (Welsh and Breder 1923; Thomas 1971; Merriner 1976; Warlen 1980).

Maturation at an early age is typical in sciaenids (Schaefer 1965; Meriner 1976; Shlossman and Chittenden 1981) and in short-lived fishes in general which tend toward *r* strategy life histories (Adams 1980). Since *L. fasciatus* is a short-lived sciaenid, rarely completing a fourth year, the small size (120 mm SL) at first maturity, attained shortly after reaching 1 yr of age, is not surprising (Ross 1978). *Larimus fasciatus* off of Texas apparently live only 2 yr and consequently mature earlier (80 mm TL) than North Carolina individuals (Standard and Chittenden in press). In addition to short life and early maturation, *r* strategists' traits are rapid growth, high fecundity (even at early ages), small maximum size, high mortality, and low maximum age (Adams 1980), all of which are related to emphasizing reproductive productivity. Banded drum have all of these characteristics as indicated in this study and by Ross (1978) and Standard and Chittenden (in press).

As banded drum became older their growth rate slows (Ross 1978; Standard and Chittenden in press), as is typical of most fishes, and they can devote relatively more energy toward reproductive activity than at earlier ages. Only the largest females (≥150 mm) appeared to spawn as early as April and continue spawning into September. Although the phenomenon of older fish having a longer spawning season has not been reported in United States east or gulf coasts sciaenids, it does occur in other fishes (Quast 1968; Grimes and Huntsman 1980).

Larimus fasciatus spawns as far north as Cape Hatteras. Although larvae have been collected off Chesapeake Bay (Berrien et al. 1978), there are no records of reproductively active adults north of Cape Hatteras and this species is rare north of Chesapeake Bay (Hildebrand and Schroeder 1928; Johnson 1978); therefore, Cape Hatteras is probably the northern limit of banded drum reproduction. *Larimus fasciatus* in spawning condition were most often collected in the nearshore waters between

Beaufort Inlet and Cape Lookout, larval distributions have not clarified the preferred spawning depth range, since larvae have been collected over a wide range of the continental shelf (Berrien et al. 1978; Powles 1980); there is, however, some tendency toward increased abundance over the inner shelf (Powles 1980). Miller et al. (in press) suggested that onshore transport by currents into estuarine nurseries of offshore spawned larvae is most favorable during the winter off North Carolina south of Cape Hatteras. Several winter spawners with estuarine dependent young spawn along the outer continental shelf (*Leiostomus xanthurus*, Dawson 1958; *Mugil cephalus*, Anderson 1958; *Brevoortia tyrannus*, Nelson et al. 1977; *Micropogonias undulatus*, Warlen 1980); thus, the young could take advantage of the inshore directed currents. A corollary to this theory indicates that summer spawners should reproduce near shore or in the estuary if larvae are to be retained in the more productive shallow waters because net current movement is offshore (Miller et al. in press). In addition to *L. fasciatus*, other fishes also spawn in nearshore or estuarine waters south of Cape Hatteras during the summer (*Cynoscion regalis*, Merriner 1976; *C. nebulosus*, Mahood 1975; *Stellifer lanceolatus* and Bairdiella chrysoura, Powles 1980).

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