Preliminary estimate of spawning frequency and batch fecundity of striped weakfish, *Cynoscion striatus*, in coastal waters off Buenos Aires province*

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The striped weakfish, *Cynoscion striatus*, is a demersal species inhabiting coastal waters of the Southwest Atlantic. It ranges from Brazil (22°35'S) to the south of Buenos Aires province (Argentina) (42°S) (Cordo, 1986). The commercial catch takes place mainly off Buenos Aires province, between 35° and 40°S, to 50 m depths. The annual catch of this species is about 20,000 metric tons,[1] corresponding to 20% of the total commercial catch of coastal species in Argentina.

Despite a variety of studies describing *C. striatus* life history, such as feeding (Ciechomski and Ehrlich, 1977; Cordo, 1986), growth (Ciechomski and Cassia, 1978), embryonic and larval development (Ciechomski and Cassia, 1982), length distributions, and sex ratios (Cousseau et al., 1986), studies on reproductive biology are rare and largely incomplete. Only one previous report has included histological analysis of the ovaries and fecundity estimates (Cassia, 1986), providing evidence that striped weakfish is a multiple spawner.

In the present study, ovaries of *C. striatus* from the coastal area of the Buenos Aires province (Argentina, Southwest Atlantic) were examined histologically, and particular attention was paid to evidence for multiple spawning and to estimates of spawning frequency and batch fecundity.

Material and methods

Cynoscion striatus was collt\ted in the zone known as "El Rincón" (Buenos Aires province, Argentina, 38°50'–40°30'S) during two research trawl cruises carried out in early November 1994 (n=179) and September 1995 (n=224) (Fig. 1). Mature females caught near "Punta del Este" (Uruguayan coast, 35°10'S–55°W) in November 1994 were also used to estimate fecundity (n=26).

Individuals were measured to the nearest centimeter (total length, TL) and weighed (total weight, TW). Length range of sampled females was 31–58 cm TL, which corresponds to 3–15 yr old individuals (Cioffi, 1992). The decision to sample only females of *C. striatus* greater than about 30 cm was based on the fact that this length is the size at maturity (Macchi and Acha[2]). Immature ovaries therefore were underrepresented in the samples.

The ovaries of individuals sampled were removed immediately after capture and fixed in 10% neutral-buffered formalin or in Davidson's fluid for two weeks. Later, fixed gonads were weighed (GW), and a portion of tissue (about 2.0 g) was removed from the center of each ovary, dehydrated in methanol, cleared in benzol, and embedded in paraffin. Tissues were sectioned at approximately 5 µm thickness, stained with Harris's hematoxylin followed by eosin counterstain. Histological classification of ovaries was based on the occurrence and relative abundance of five stages of oocyte development (Table 1) as well as on the occurrence and intensity of atresia. The terminology used in the description of oocyte stages was adapted from Forberg (1982), and the classification of atresia followed that given by Hunter and Macewicz (1985). Ovaries were classified into eight stages: 1) immature, 2) developing early, 3) developing late, 4) fully developed, 5) gravid, 6) partially spent, 7) spent, and 8) resting. This classification is a modification of that given by Mayer et al. (1988). Oocyte measurements were taken of the ovaries in different maturity stages (3 ovaries for each stage). Oocytes with visible nuclei showing were measured along the longest axes with an ocular micrometer. About 10 fields of view per histological section were chosen at random (Fig. 2).

To estimate the spawning fraction, only the samples collected during November 1994 were used. The percentage of spawning fe-

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[1] Secretaría de Agricultura, Pesca y Alimentación. 1996. Flota pesquera Argentina (capturas marítimas totales). [Available from SAPyA., Paseo Colón 982, Buenos Aires, Argentina.]

[2] Macchi, G. J., and M. E. Acha. In press. Chapter 4: Aspectos reproductivos de las principales especies de peces. *In* Lasta (ed.), Resultados de la campaña H-13/94, Serie Informes Técnicos INIDEP.

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males was determined by estimating the incidence of fish with postovulatory follicles (POF) (Hunter and Goldberg, 1980). These structures were classified as day-0, day-1, or day-2 postovulatory follicles, following the description by Goldberg et al. (1984) for *Sardinops sagax* and by Melo (1994) for *Engraulis capensis*.

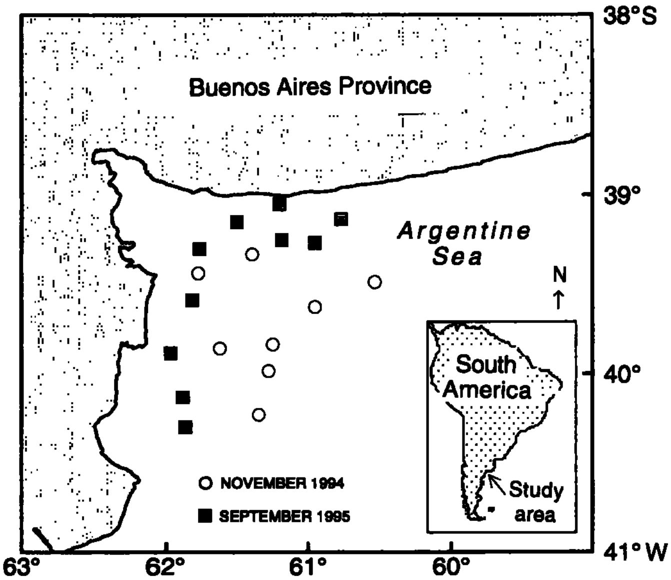

Figure 1
Location where samples of female striped weakfish were collected off "El Rincón" area.

The proportion of spawning females was estimated from the different stages of POF, but the spawning frequency was determinated by taking the average of the percentages of day-0 and day-1 spawning females (Fitzhugh et al., 1993).

Batch fecundity (BF) (number of oocytes released per spawning) was estimated gravimetrically with the hydrated oocyte method (Hunter et al., 1985) on fixed ovarian samples. Hydrated ovaries that contained new postovulatory follicles were not used for this estimation. Batch fecundity was determined for 41 females (17 from "El Rincón" and 24 from the Uruguayan coast). Three 0.1-g tissue subsamples were collected from the anterior, middle, and posterior sections of one ovary of each pair. These subsamples were weighed to the nearest 0.00001 g. All hydrated oocytes in each subsample were counted under stereoscopic microscope (magnification of 6×). Batch fecundity for each female was the product of the mean number of hydrated oocytes per unit weight and the total weight of the ovaries. Relative fecundity (RF) (hydrated oocytes per gram of body weight) was calculated as the batch fecundity divided by female weight (without ovary). To compare the "El Rincón" data with those from the Uruguayan coast, the length ranges coincident with the two zones were truncated between 40 and 50 cm TL ("El Rincón," n=15; Uruguayan coast, n=17). The fecundity values and the coefficients of the batch fecundity to

Table 1
Morphological changes observed in the different oocyte growth phases. Adapted from Forberg (1982).

Oocyte growth stages	Description
First growth phase Cromatin nucleolus stage Early nucleolus stage Late nucleolus stage	Previtellogenic oocytes with diameters smaller than 100 µm. Cytoplasm is basophilic and the nucleus shows a number of nucleoli situated peripherally. Follicular cells are flattened and become visible on the outer surface of oocyte.
Second growth phase Yolk vesicle stage	Diameter ranged between 100–250 µm. Cytoplasm is basophilic and shows small uncolored vacuoles (yolk vesicles). Granulosa and follicular thecae are distinguished and the zona radiata becomes visible around the periphery of oocyte.
Primary yolk stage	Diameter ranged between 250 and 350 µm. Numerous eosinophilic yolk globules appear between the yolk vesicles. These yolk globules are composed mainly of proteins. The zona radiata and the follicle epithelium are more prominent.
Secondary yolk stage	Diameter between 400 and 600 µm. The yolk globules have multiplied and increased in size, occupying all the cytoplasm. The nucleus exhibits an irregular shape, and the zona radiata increases in thickness.
Tertiary yolk stage or final oocyte maturation	Oocyte diameter ranged between 600 and 700 µm. In the first instance, the nucleus is displaced to the animal pole (migratory nucleus stage). The nuclear membrane disintegrates and the yolk globules tend to coalesce. In the section, these oocytes appear with a cytoplasm weakly eosinophilic and an irregular shape.

total length relationships obtained for both areas were compared with a test of equality of means and a test of equality of coefficients (Draper and Smith, 1981). The relations of batch fecundity to total length and total weight (without ovary) were assessed with regression analysis (Draper and Smith, 1981). Significance of these relations were evaluated by testing if the slope of the regression was significantly different from zero.

Results

Oocyte diameter distributions of different maturity stages (immature to gravid) of *C. striatus* show that this species is a multiple spawner (Fig. 2). The gravid ovaries show four main groups of oocytes. The first group is composed mainly of primary growth oocytes (smaller than 100 µm). The second group is composed of partially yolked oocytes in several stages ranging approximately from 100 to 300 µm. The third group is formed by advanced yolked oocytes ranging between 400 to 600 µm. The fourth group corresponds to the hydrated oocytes between 600 to 700 µm.

During September, 95% of the females were found in the developing stages (early and late), with a small percentage (3%) in the fully developed phase (Fig. 3). The samples obtained during early November were composed mainly of females in the partially spent stage with postovulatory follicles; about 11% of the samples were gravid females. These results indicate that the beginning of spawning of *C. striatus* in "El Rincón" is in October.

Of the mature females taken in November, 12% had hydrated oocytes, 11% had new postovulatory follicles (phase 0), 13% had day-1 postovulatory follicles, and 11% had old postovulatory follicles (phase 2) (Table 2). Therefore, each female was calculated to spawn every 7–9 days. The average of the percentages of day-0 and day-1 spawning females was

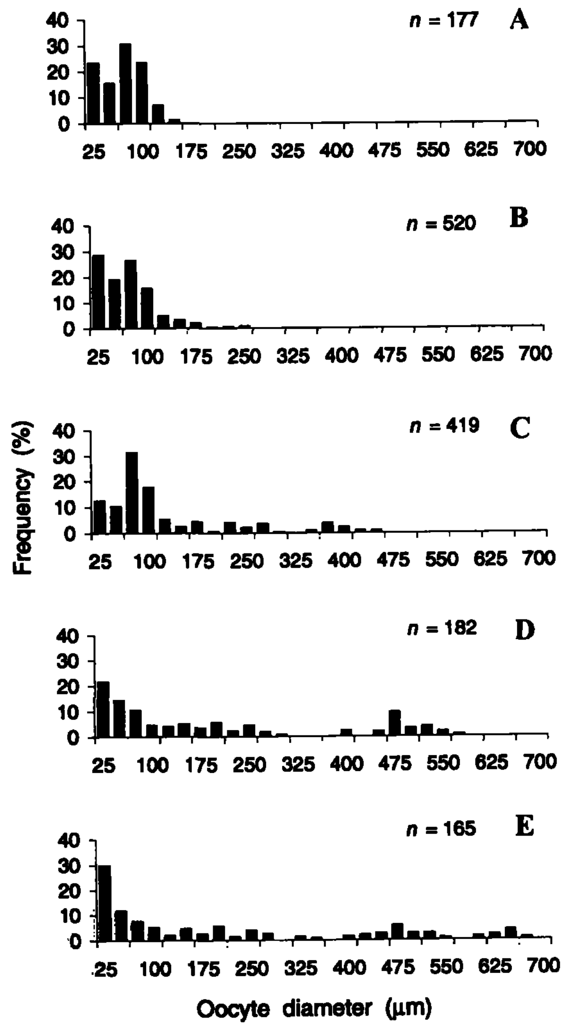

Figure 2

Oocyte diameter distributions for different maturity stages: A = immature; B = developing early; C = developing late; D = fully developed; and E = gravid.

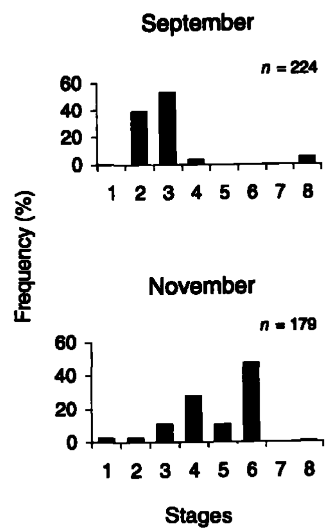

Figure 3

Maturity-stage frequency of striped weakfish during September 1995 and November 1994. Stages: 1 = immature; 2 = developing early; 3 = developing late; 4 = fully developed; 5 = gravid; 6 = partially spent; 7 = spent; and 8 = resting.

Table 2

Number of reproductively active females of *C. striatus* sampled in "El Rincón" area based on histological staging for determination of spawning frequency. POF = postovulatory follicles; CI = confidence interval.

Day of month (November)	Hydrated oocytes	POF day-0	POF day-1	POF day-2	Total mature
2	1	2	2	4	23
3	3	2	2	5	28
3	1	3	4	1	13
3	5	1	0	1	13
4	0	1	8	5	27
5	4	7	1	2	22
5	1	0	0	2	17
6	2	3	4	1	17
8	1	0	2	0	12
Total	18	19	23	21	172
% (average)	11.71	11.09	13.44	10.65	
95% CI	12 ±7	11 ±7	13 ±8	11 ±4	

12% (±6), which yielded an estimation that spawning occurred every 8 days.

The range in batch fecundity for females caught in "El Rincón" was 50,000 to 450,000 hydrated oocytes for fish between 40 and 53 cm TL. The samples collected from the Uruguayan coast ranged from 38,000 to 360,000 hydrated oocytes for females of 34 to 52 cm. A test of equality of means for the batch fecundity values of both zones showed no significant difference ($P>0.56$). A test of equality of coefficients indicated that no significant difference existed between the equations for BF vs. TL for the two areas ($P>0.05$). The general equations for the total length and total weight were determined by combining all data (Fig. 4, A and B). No statistical differences were observed between the mean values of relative fecundity obtained for both zones ($P>0.25$). This parameter ranged between 50 and 420 hydrated oocytes per gram of female (ovary free); an increase in the number of oocytes with size was observed (Fig. 4, C and D).

Discussion

The results obtained indicate that striped weakfish is a multiple spawner with indeterminate annual fecundity. Hence, the potential annual fecundity is not fixed prior to the onset of spawning, and unyolked oocytes continue to mature and to be spawned during the reproductive season (Hunter et al., 1992). This assumption is based on two lines of evidence: 1) the presence of maturing ovaries with postovulatory follicles (partially spent stage), which indicates that after spawning one batch of eggs, a new batch develops and is released; and 2) oocyte size frequency, which shows a continuous distribution of growing vitellogenic oocytes.

Reproductive activity of striped weakfish in the coastal waters of Buenos Aires province ranges from October to March, with a main peak in November (Cassia, 1986). The histological examination of ovaries obtained during September did not show evidence of spawning, but those taken in early November indicated considerable reproductive activity, with a high proportion of postovulatory follicles and the appearance of hydrated oocytes. This corroborates the hypothesis that the spawning of *C. striatus* in "El Rincón" area generally begins in October. Unfortunately, it was not possible to sample this species during the rest of the spawning season, which lasts about 6 mo. according to Cassia (1986). The long reproductive season of this species has also been observed in other sciaenids inhabiting temperate waters, such as *Seriphus politus* (7 mo.) (De Martini and Fountain, 1981), *Cynoscion nebulosus* (7 mo.) (Brown-Peterson et al., 1988), *Micropogonias undulatus* (7 mo.) (White and Chittenden, 1977; Barbieri et al., 1994), *Genyonemus lineatus* (7 mo.) (Love et al., 1984), *Cynoscion nothus* (6 mo.) (De Vries and Chittenden, 1982) and *Cynoscion regalis* (5 mo.) (Merriner, 1976). In Argentinian coastal waters, the main sciaenid associated with *C. striatus* is the white croaker (*Micropogonias furnieri*), which has reproductive activity from November to March (Macchi and Christiansen, 1996).

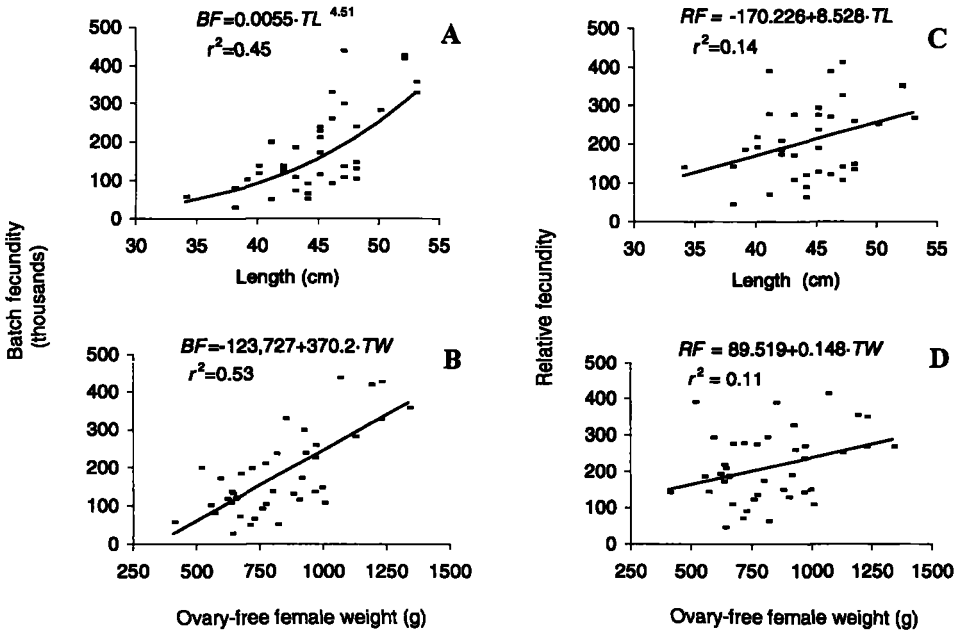

Figure 4

Batch fecundity as a function of total length (**A**) and total weight (without ovary) (**B**). Relative fecundity as a function of total length (**C**) and total weight (without ovary) (**D**).

Because vitellogenic oocytes are recruited continually during the reproductive season, it is necessary to determine the batch fecundity and the number of spawnings in the season in order to estimate total egg production (Hunter et al., 1985). Spawning frequency estimated from the percentage of hydrated ovaries (12%) was similar to those calculated with postovulatory follicles (11–13%). The average between day-0 and day-1 POF's (12 ±6%) indicates that spawning occurred once every 8 days during the main peak of the reproductive season (November). Daily spawning fraction of *C. striatus* was similar to that reported for three other scienids: *Seriphus politus* (De Martini and Fountain, 1981), *Genyonemus lineatus* (Love et al., 1984) and *Cynoscion nebulosus* (Brown-Peterson et al., 1988), but was lower than estimates for *Pogonias cromis* (31%) (Fitzhugh et al., 1993). Annual spawning frequency estimated for *Sciaenops ocellatus* (Wilson and Nieland, 1994) and *Cynoscion regalis* (Lowere-Barbieri et al., 1996) varied widely, 3 to 80 days and 2 to 13 days, respectively. Daily spawning percentage of white croaker (*Micropogonias furnieri*) in the Southwest Atlantic was 8.83% (Macchi et al., in press), indicating that the average interval between spawnings for this sciaenid is about 12 days .

Cassia (1986) estimated total fecundity for *C. striatus* by counting the number of growing oocytes, which is inappropriate for a multiple spawning species (Hunter and Goldberg, 1980). This author estimated a total fecundity of 600,000 oocytes for one 40-cm-TL female, when the batch fecundity for that length is about 100,000 hydrated oocytes. In the present study, analysis of variance applied to the fecundity data from "El Rincón" and the Uruguayan coast indicated no statistical differences between these areas. Batch fecundity was a power function of length and a linear function of ovary-free body weight and ranged between 50,000 (34 cm TL) and 450,000 (53 cm TL) hydrated oocytes. Batch fecundity values estimated for striped weakfish were higher than those obtained for smaller sciaenids, such as *Genyonemus lineatus* (800–37,200 oocytes) (Love et al., 1984) and *Seriphus politus* (5,000–90,000 oocytes) (De Martini and Fountain, 1981). Sciaenids with length ranges similar to *C. striatus,* such as *Cynoscion regalis* (Lowere-Barbieri et al., 1996) and *Cynoscion nebulosus* (Brown-Peterson et al., 1988), show slightly higher batch fecundity values. The relations between batch fecundity vs. length and batch fecundity vs. weight for these species had relatively low coefficients of determination, similar to those for striped weakfish. The mean relative fecundity for *C. striatus* (210 ±35 oocytes/g ovary-free body weight) was less than that obtained for *Cynoscion nebulosus* (451 ±43 oocytes) (Brown-Peterson et al., 1988) and

Cynoscion regalis (200–750 oocytes) (Lowere-Barbieri et al., 1996).

Accurate annual fecundity estimations are difficult to determine for multiple spawning fishes with an extended reproductive season (Brown-Peterson et al., 1988). During November–March, a female *C. striatus* would spawn 22 times with a spawning frequency of 8 days. Consequently, annual fecundity estimates for a 40.0-cm-TL female would be about 2.0 million eggs. However, annual egg production depends on spawning frequency, and it is possible that this parameter varies during the reproductive season and between years (Lowerre-Barbieri et al., 1996). The annual fecundity estimate for *C. striatus* was similar to that obtained for white croaker of the Rio de la Plata estuary (*Micropogonias furnieri*) (1.8 million eggs for a 40.0 cm TL female) (Macchi et al., in press). Both species are among the most heavily exploited coastal resources in Argentina and Uruguay.

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Literature cited

Barbieri, L. R., M. E. Chittenden Jr., and S. K. Lowerre-Barbieri.
1994. Maturity, spawning, and ovarian cycle of Atlantic croaker, *Micropogonias undulatus*, in the Chesapeake Bay and adjacent coastal waters. Fish. Bull. 92:671–685.

Brown-Peterson, N., P. Thomas, and C. R. Arnold.
1988. Reproductive biology of the spotted seatrout, *Cynoscion nebulosus*, in south Texas. Fish. Bull. 86(2):373–388.

Cassia, M.C.
1986. Reproducción y fecundidad de la pescadilla de red (*Cynoscion striatus*). Publ. Com. Téc. Mix. Fr. Mar. 1(1):191–203.

Ciechomski, J. D. de, and M. C. Cassia.
1978. Studies on the growth of juveniles of *Cynoscion striatus* in the sea and in aquaria. J. Fish Biol. 13:521–526.
1982. Observaciones sobre embriones, larvas y juveniles de la pescadilla *Cynoscion striatus*. Rev. Invest. Des. Pesq. INIDEP, Mar del Plata 3:5–13.

Ciechomski, J. D. de, and M. D. Ehrlich.
1977. Alimentación de juveniles de pescadilla *Cynoscion striatus* (Cuvier, 1829) Jordan & Evermann, 1889 en el mar y en condiciones experimentales. Pisces, Sciaenidae. Physis (sec. A) 37(93):1–12.

Cioffi, C. A.
1992. Evaluación de la pescadilla de red (*Cynoscion striatus*) en la Zona Común de Pesca Argentino-Uruguaya, en el otoño de 1989. M.S. thesis, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina, 40 p.

Cordo, H. D.
1986. Estudios biológicos sobre peces costeros con datos de dos campañas de investigación realizadas en 1981. III: La pescadilla de red (*Cynoscion striatus*). Publ. Com. Téc. Mix. Fr. Mar. 1(1):15–27.

Cousseau, M. B., C. P. Cotrina, H. D. Cordo, and G. E. Burgos.
1986. Análisis de datos biológicos de corvina rubia (*Micropogonias furnieri*) y pescadilla de red (*Cynoscion striatus*) obtenidos en dos campañas del año 1983. Publ. Com. Téc. Mix. Fr. Mar. 1(2):319–332.

DeMartini, E. E., and R. K. Fountain.
1981. Ovarian cycling frequency and batch fecundity in the queenfish, *Seriphus politus*: attributes representative of serial spawning fishes. Fish. Bull. 79(3):547–560.

DeVries, D. A., and M. E. Chittenden Jr.
1982. Spawning, age determination, longevity, and mortality of the silver seatrout, *Cynoscion nothus*, in the Gulf of Mexico. Fish. Bull. 80(3):487–500.

Draper, N., and H. Smith.
1981. Applied regression analysis, 2nd ed. J. Wiley & Sons, New York, NY, 709 p.

Fitzhugh, G. R., B. A. Thompson, and T. G. Snider III.
1993. Ovarian development, fecundity, and spawning frequency of black drum *Pogonia cromis* in Louisiana. Fish. Bull. 91:244–253.

Forberg, K. G.
1982. A histological study of development of oocytes in capelin, *Mallotus villosus villosus* (Muller). J. Fish Biol. 20:143–154.

Goldberg, S. R., V. H. Alarcón, and J. Alheith.
1984. Postovulatory follicle histology of the Pacific sardine, *Sardinops sagax*, from Peru. Fish. Bull. 82(2):443–445.

Hunter, J. R., and S. R. Goldberg.
1980. Spawning incidence and batch fecundity in northern anchovy, *Engraulis mordax*. Fish. Bull. 77(3):641–652.

Hunter, J. R., and B. J. Macewicz.
1985. Rates of atresia in the ovary of captive and wild northern anchovy, *Engraulis mordax*. Fish. Bull. 83:119–136.

Hunter, J. R., N. C. H. Lo, and R. J. H. Leong.
1985. Batch fecundity in multiple spawning fishes. *In* R. M. Lasker (ed.), An egg production method for estimating spawning biomass of pelagics fish: application to the northern anchovy, *Engraulis mordax*, p. 67–77. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 36.

Hunter, J. R., B. J. Macewicz, N. C. H. Lo, and C. A. Kimbrell.
1992. Fecundity, spawning, and maturity of female Dover sole *Microstomus pacificus*, with an evaluation of assumptions and precision. Fish. Bull. 90:101–128.

Love, M. S., G. E. McGowen, W. Westphal, R. J. Lavenberg, and L. Martin.
1984. Aspects of the life history and fishery of the white croaker, *Genyonemus lineatus* (Sciaenidae), off California. Fish. Bull. 82:179–198.

Lowerre-Barbieri, S. K., M. E. Chittenden Jr., and L. R. Barbieri.
1996. Variable spawning activity and annual fecundity of weakfish in Chesapeake Bay. Trans. Am. Fish. Soc. 125:532–545.

Macchi, G. J., and H. E. Christiansen.
1996. Análisis temporal del proceso de maduración y determinación de la incidencia de atresias en la corvina rubia (*Micropogonias furnieri*). Frente Marítimo 16: 93–101.

Macchi, G. J., E. M. Acha, and C. A. Lasta.
In press. Desove y fecundidad de la corvina rubia (*Micropogonias furnieri* Desmarest, 1823) del estuario del Río de la Plata, Argentina. Bol. Inst. Esp. Ocean.

Mayer, I., S. E. Shackley, and J. S. Ryland.
1988. Aspects of the reproductive biology of the bass, *Dicentrarchus labrax* L.I. An histological and histochemical study of oocyte development. J. Fish Biol. 33:609–622.

Melo, Y. C.
1994. Spawning frequency of the anchovy *Engraulis capensis*. S. Afr. J. Mar. Sci. 14:321–331.

Merriner, J. V.
1976. Aspects of the reproductive biology of the weakfish, *Cynoscion regalis* (Sciaenidae), in North Carolina. Fish. Bull. 74(1):18–26.

White, M. L., and M. E. Chittenden Jr.
1977. Age determination, reproduction, and population dynamics of the Atlantic croaker, *Micropogonias undulatus*. Fish. Bull. 75(1):109–124.

Wilson, C. A., and D. L. Nieland.
1994. Reproductive biology of red drum, *Scienops ocellatus*, from the neritic waters of the northern Gulf of Mexico. Fish. Bull. 92(4):841–850.