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Reproduction of black drum (*Pogonias cromis*) in the Río de la Plata estuary, Argentina☆

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Abstract

The reproductive biology of black drum, *Pogonias cromis*, collected during August 1998–January 1999 from commercial catches in Samborombón Bay (Río de la Plata estuary, Argentina) was studied using macroscopic and histological analysis of the gonads. Black drums are multiple spawners with indeterminate annual fecundity that spawn from October to January. Spawning frequency, determined from the percentage of females with postovulatory follicles, ranged between 27 and 32% during the spawning peak (October–November) in 1998. At these frequencies, each female on average spawned a new batch of eggs every 3–4 days during this period. Batch fecundity was positively correlated with total length and total weight (ovary-free) and ranged between 90 000 (66 cm TL) and 2 600 000 (130 cm TL) hydrated oocytes. Relative fecundity ranged from 22 to 146 hydrated oocytes per gram of ovary-free weight.

Keywords: *Pogonias cromis*; Black drum; Southwest Atlantic; Río de la Plata estuary; Reproduction

1. Introduction

The black drum *Pogonias cromis* is a demersal coastal species distributed along the western Atlantic Ocean from Massachusetts, USA, to the south of Buenos Aires Province in Argentina (Nieland and Wilson, 1993). It is an estuarine-dependent species (Patillo et al., 1997) and is the largest sciaenid observed in the Río de la Plata estuary. Black drum is commercially harvested in inshore waters of Samborombón Bay, a semi-enclosed region inside the Río de la Plata estuary. Fishing effort occurs mainly between late winter and summer (Urteaga, 2001), but is especially high during spring (October–December), when *P. cromis* forms large schools in shallow waters. This behavior contributes to intensified commercial and recreational activity on this species. Until 1997, the recreational catch for black drum was greater than the commercial landings, but during the two last years fishing pressure has increased because the traditional resources, such as the whitemouth croaker (*Micropogonias furnieri*), have decreased drastically (Carozza et al., in press). During 1999,

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the commercial catch of *P. cromis* reached about 300 t in Argentina (Urteaga, 2001).

The black drum have been extensively studied in the Gulf of Mexico where it is relatively abundant, with an annual catch of around 5000 t (Fitzhugh et al., 1993). A variety of studies describing growth (Richards, 1973; Murphy and Taylor, 1989; Beckman et al., 1990; Jones and Wells, 1998), feeding (Silverman, 1979) and embryonic and larval development (Joseph et al., 1964) have been done. Different aspects of black drum reproduction in the northern Gulf of Mexico have been reported by Nieland and Wilson (1993), Saucier and Baltz (1993) and Fitzhugh et al. (1993). However, studies on the reproductive biology of this species in waters of South America have not been documented.

Our objective was to provide information on black drum reproduction in the Río de la Plata estuary. We characterized ovarian development and determine the spawning season of this species. Moreover, we estimated the spawning frequency and fecundity of *P. cromis* at the southern limit of its geographical distribution.

2. Materials and methods

2.1. Fish samples

Black drum were sampled monthly from commercial landings carried out between August 1998 and January 1999, except in September 1998. All individuals were captured from the estuarine waters of Samborombón Bay (Fig. 1). Landings were taken mainly by trawls during August and October and by gillnets, with a 280 mm mesh, in the other months. Total length (TL), total weight (TW) and macroscopic maturity stages were recorded for each fish sampled

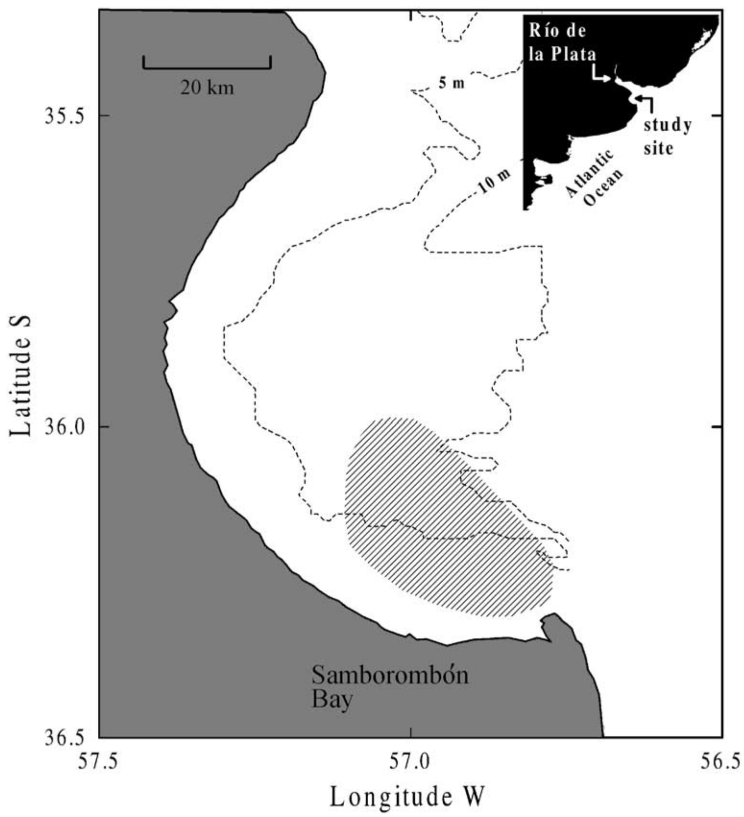

Fig. 1. Location of black drum fishing ground in Samborombón Bay (shadowed area) during August 1998–January 1999.

($n = 528$). A maturity scale of five stages designed for biological studies was employed: (1) immature, (2) developing and partially spent, (3) spawning (gravid and running), (4) spent and (5) resting (Macchi and Diaz Astarloa, 1996). This macroscopic classification was used for the temporal analysis of the relative composition of maturity stages. Ovaries of the females sampled were removed after capture and fixed in 10% neutral buffered formalin.

2.2. Laboratory processing

Fixed gonads were weighed and a portion of tissue was removed from each ovary, dehydrated in methanol, cleared in benzol and embedded in paraffin. Tissue samples were sectioned at 4 μm thickness, stained with Harris's haematoxylin followed by eosin counterstain. Histological classification was based on five stages of oocyte development: primary growth, cortical alveoli, partially yolked, advanced yolked and hydrated (Wallace and Selman, 1981) as well as on the occurrence of atresia. The classification of atresia and the atretic condition of the ovaries (Table 1) were those given by Hunter and Macewicz (1985). The description of the postovulatory follicle (POF) stages was adapted from that given by Fitzhugh et al. (1993) for *P. cromis* from Louisiana.

Five gravid ovaries (with hydrated oocytes) were randomly selected during the main spawning peak of black drum for the determination of oocyte diameter distribution. Oocyte samples ($n = 346$) were removed after fixation and the longest axe were measured (±40 μm) with an ocular micrometer.

Three samples of 100 hydrated oocytes were removed from the ovaries of 20 females (14 specimens collected in October and six in December). These oocytes were measured and each sample was rinsed in distilled water, dried for 20 h at 60 °C and weighed (±0.1 mg). A single-classification analysis of variance was used to compare the mean dry weight of hydrated oocytes sampled during these months (Draper and Smith, 1981).

2.3. Spawning frequency and fecundity estimation

Spawning frequency was estimated from samples collected from October to December. The daily fraction of spawning females was estimated by the incidence of fish with day-0 and day-1 POFs separately (Hunter and Goldberg, 1980). Spawning frequency was determined based on the average of the percentages of day-0 and day-1 spawning females (Fitzhugh et al., 1993; Macchi, 1998). Mean and variance of this parameter were calculated according to the equations developed by Picquelle and Stauffer (1985), which allow weighing of each station according to subsample size.

Batch fecundity (BF; number of oocytes released per spawning) was estimated gravimetrically with the hydrated oocyte method on fixed ovarian samples (Hunter et al., 1985). Ovaries selected showed no evidence of recent spawning (no POF). BF was determined for 42 females (28 from October and 14 from December). Three pieces of ovary, approximately 0.1 g each, were removed from the anterior, middle and posterior parts of one gonad, weighed with a precision of 0.1 mg and the number of hydrated oocytes counted. BF 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 eggs per gram of ovary-free body weight) was calculated as the BF divided by female weight (without ovaries). The relationships of BF to total length and to total weight (ovary-free) were described using standard regression analysis. Comparisons between the different months were based on coincident length ranges of the samples, and an analysis of covariance was applied (Draper and Smith, 1981).

Table 1
Atretic states according to Hunter and Macewicz (1985)

Atretic states of the ovary	Description
0	Mature ovary with yolked oocytes and no alpha atresia
1	Alpha atresia of yolked oocytes where <50% of yolked oocytes are affected
2	Alpha atresia of yolked oocytes where ≥50% of yolked oocytes are affected
3	No yolked oocytes present and beta atresia is observed

Table 2
Statistic data from the samples of black drum collected between August 1998 and January 1999 (only mature individuals were included)

Months	Average TL (cm)	TL range (cm)	Males (%)	*n*
August	95	65–125	41.00	61
October	85	52–130	60.76	257
November	98	82–114	78.50	106
December	97	78–112	65.00	81
January	95	79–110	55.00	18

3. Results

3.1. Length distributions and sex ratio

Length distributions obtained for each month did not differ between sexes (KS test, $P > 0.20$). During August and October, the length range was larger than other months (Table 2). From November to January, when samples were collected only with gillnets, fish size ranged mainly between 80 and 110 cm TL. Males prevailed during all the period concerned, except in August, when females dominated the sample with a contribution of about 60% (Table 2).

3.2. Spawning pattern

POFs were identified in mature females with yolked oocytes, which indicates that after spawning one batch of eggs a new batch develops and is released. POFs were classified as day-0 and day-1, according to the elapsed time from spawning. Day-0 POF (elapsed time from spawning <24 h) has an irregular and convoluted shape with many folds; the granulosa cells are aligned with a prominent nucleus and the lumen is clearly visible (Fig. 2A). Day-1 POF (elapsed time from spawning >24 h) shows degenerative process, the linear appearance of the granulosa cells is not distinct and the lumen becomes reduced; the granulosa and theca cells cannot be clearly distinguished (Fig. 2B).

Oocyte diameter distribution of fully developed females showed three main groups of oocytes, with a large degree of overlap and no clear limits between 200 and 800 μm (Fig. 3). Oocytes with size less than 200 μm, corresponding to primary growth stage, were not considered. Histological analysis showed that the first group, with a modal peak in 200 μm, is composed mainly of cortical alveolus oocytes but includes partially yolked oocytes in the beginning of yolk deposition. The second group is mainly composed of advanced yolked oocytes ranging approximately from 500 to 800 μm. The third group corresponds to the hydrated oocytes between 1100 and 1400 μm.

3.3. Spawning season

During August in Samborombón Bay, 60% of the sampled individuals were found in the developing phase but no spawning females (with hydrated oocytes or POF) were observed (Fig. 4). By October, 40% of the females sampled were gravid (with hydrated oocytes). During November and December, the percentages of gravid females remained relatively high and ovaries in the spent stage were observed in very low proportion in the last month. The sample obtained during January was small ($n = 18$) and all females were in the partially spent stage, but hydrated oocytes were not observed. During this month, a high percentage (about 50%) of males were in the spent or resting stage. Histological examination of ovaries collected between August and January showed POFs from October to January (Fig. 5). Samples of black drum collected throughout the spawning season showed a high incidence of females with atresia of yolked oocytes (alpha and beta stages). However, the atretic condition of the ovaries was very low (atretic state 1) with a high percentage of healthy yolked oocytes (>50%), indicating that females were capable of spawning.

3.4. Spawning frequency

In October, spawning frequency was estimated by examining the ovarian tissue of 118 mature females with vitellogenic oocytes collected over about 2 weeks. Of the sampled females, 28% had day-0 POFs and 26% had day-1 POFs (Table 3). The average between these percentages (27%; S.D. 6.21) indicates an interval between spawning of 3.6 days for this month. During November and December, spawning frequency was estimated from only one sampling data (Table 3). In November, the average between the percentages of POF-0 and POF-1 was similar to that in October (32%), but during December spawning

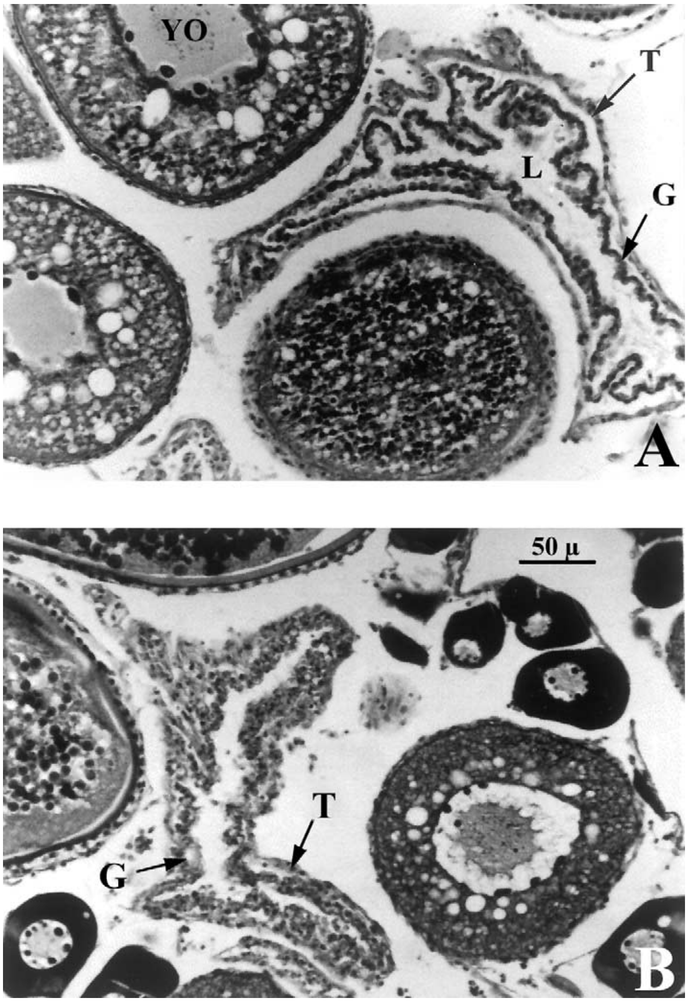

Fig. 2. POFs from female black drum at different stages: (A) day-0, cord-like appearance of the granulosa layer can be observed; (B) day-1, reduction in size and degeneration of follicles are evident. T: thecal layer; G: granulosa layer; L: lumen; YO: yolked oocytes.

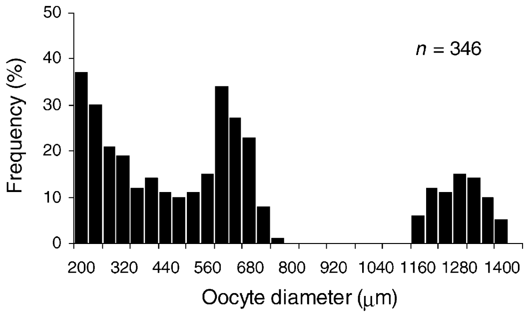

Fig. 3. Oocyte diameter distribution for ovaries of black drum in gravid stage (containing hydrated oocytes).

frequency was about 14%. The last percentage indicates that each female would have spawned once every 7 days during this month.

3.5. Fecundity

BF estimated for 42 females (28 in October and 14 in December) ranged from 90 000 to 2 600 000 hydrated oocytes for fish between 66 and 130 cm TL. Analysis of covariance based on coincident length ranges of the females sampled revealed that no difference could be discerned between these months at

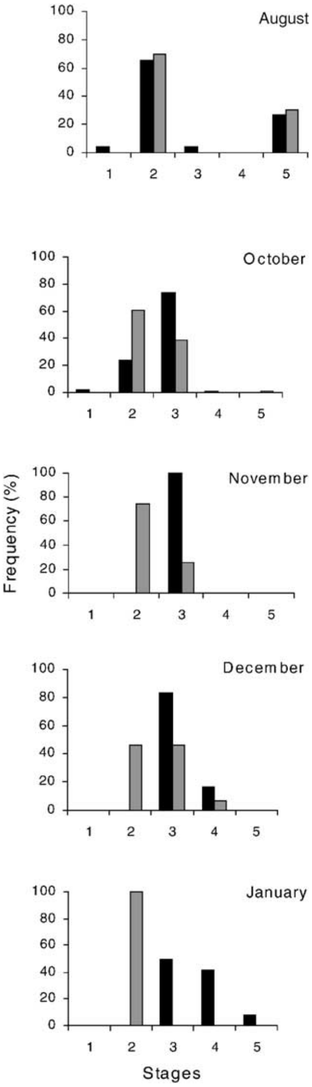

Fig. 4. Maturity-stage frequency of males (dark bars) and females (white bars) black drum sampled in Samborombón Bay between August 1998 and January 1999. Macroscopic maturity stages: (1) immature; (2) developing and partially spent; (3) spawning (gravid and running); (4) spent; (5) resting.

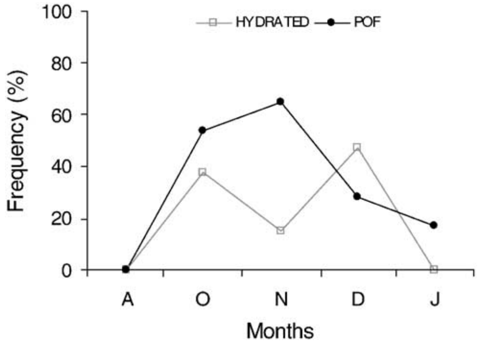

Fig. 5. Frequency of black drum females with hydrated oocytes or POFs sampled in Samborombón Bay between August 1998 and January 1999.

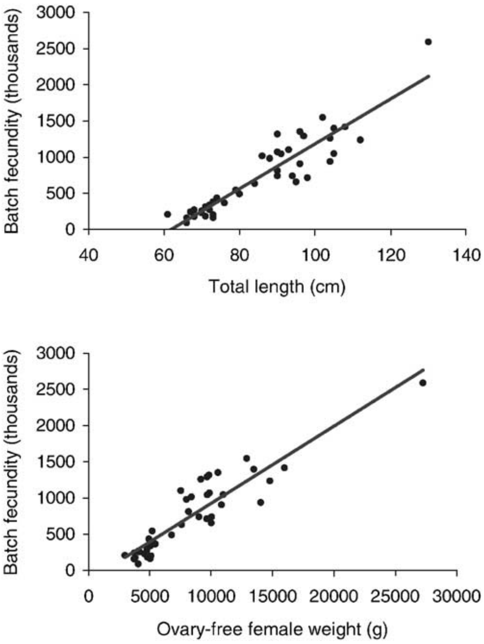

Fig. 6. BF of black drum as a function of total length and total weight (without ovary).

the 5% error level; thus, we combined the data from October and December. Black drum BF showed an increase with the total length and weight (Fig. 6) described by the equations:

$$BF = 31\,008TL - 1\,916\,300 \quad (r^2 = 0.85),$$
$$BF = 106.5TW - 136\,140 \quad (r^2 = 0.84)$$

RF ranged from 22 to 146 hydrated oocytes per gram of female (ovary-free) and the mean values obtained from October and December were 75 oocytes g^{-1} (S.D. 31) and 98 oocytes g^{-1} (S.D. 27), respectively.

Even though the number of hydrated oocytes per batch was similar in females sampled during October and December, egg size decreased at the end of the

Table 3
Proportion of black drum females in reproductive activity that were histologically staged for estimation of spawning frequency

October 1998 (samples)	Hydrated oocytes	Day-0 POF	Day-1 POF	Yolked oocytes and no POF	Total mature females (*n*)
1	0.53	0.21	0.21	0.05	19
2	0.64	0.07	0.29	0.00	14
3	0.41	0.47	0.12	0.00	17
4	0.30	0.30	0.30	0.10	10
5	0.35	0.40	0.25	0.00	20
6	0.26	0.24	0.42	0.08	38
Average	0.41	0.28	0.26		
Coefficient of variation	0.16	0.18	0.23		
November 1998	0.15	0.35	0.30	0.20	20
December 1998	0.46	0.21	0.08	0.25	28

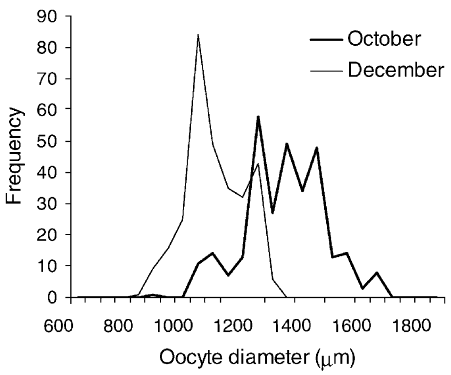

Fig. 7. Frequency distribution of the hydrated oocyte diameter of black drum females sampled during October and December 1998.

spawning season. Hydrated oocytes of gravid females collected in October ranged between 900 and 1700 μm, while during December oocyte diameter for individuals at the same length ranged between 750 and 1350 μm (Fig. 7). Taking into account that the size differences could be associated with the degree of hydration, we compared the dry weight of oocytes sampled during these months. The average dry weight of samples of 100 hydrated oocytes (4.24 mg; S.D. 0.40) in October was significantly higher ($P < 0.01$) than in December (3.43 mg; S.D. 0.28). This result suggests that the egg yolk reserves may decline during the course of spawning, being lower for the last oocyte batches.

4. Discussion

We observed black drum aggregations at southern Samborombón Bay in depths of less than 10 m, mainly from October to December. During this period, males dominated the samples analyzed. Differences in sex ratios have been also noted for *P. cromis* in the Gulf of Mexico (Fitzhugh et al., 1993) and for other sciaenids such as *M. furnieri* (Macchi et al., 1996). It is believed that these differences in sex ratios are due to spatial segregation by sex during spawning (Macchi et al., 1996). In fact, October–December was considered the main spawning period for black drum in the Samborombón Bay, based on our macroscopic and histological analysis of gonads. The examination of ovaries obtained during August did not show evidence of spawning, but those taken in October indicated considerable reproductive activity with a high percentage of ovaries with POFs or hydrated oocytes. Although we did not obtain samples during September, it is possible that the spawning of *P. cromis* in Samborombón Bay begins in this month. Reproductive activity in the area decreased during January, when the black drum aggregations diminished, indicating the end of the spawning season. Our results on the reproductive cycle of this species agree with previous reports for the Gulf of Mexico region, which describe the spawning season of black drum mainly in spring (Peters and McMichael, 1990; Fitzhugh et al., 1993; Saucier and Baltz, 1993; Nieland and Wilson, 1993).

Black drum of the Río de la Plata estuary is a multiple spawner, based on our observations of maturing ovaries with POFs and yolked oocytes. Furthermore, different lines of evidence support the assumption of indeterminate annual fecundity in this species, according to Hunter et al. (1992): (1) oocyte size frequency distribution of gravid females shows different batches of growing oocytes, which indicates a continuous recruitment of unyolked oocytes into the advanced group; (2) BF did not change over the spawning season; (3) mean diameter of the hydrated oocytes did not increase at the end of the spawning season. On the other hand, a similar spawning pattern has been suggested for this species in the Gulf of Mexico (Peters and McMichael, 1990; Nieland and Wilson, 1993). Female black drum of Samborombón spawn on average once every 3 or 4 days during October–November. Close to the end of the spawning season (December), the percentage of females with POFs decreased indicating that spawning occurred about once every 7 days. Nevertheless, this value was considered a preliminary estimate because it was calculated from only one sample ($n = 28$). During the reproductive peak (October–November) spawning frequency was similar to that estimated for black drum in the Gulf of Mexico (Fitzhugh et al., 1993; Nieland and Wilson, 1993) and for red drum (*Sciaenops ocellatus*) of the same region (Wilson and Nieland, 1994).

Analysis of covariance applied to the BF data obtained during October and December 1998 indicated no statistical differences between these months. The number of hydrated oocytes was fitted to a linear function of total length and ovary-free body weight, similar to that reported for *P. cromis* in the Northern Gulf of Mexico (Nieland and Wilson, 1993). We estimated that a 10 kg TW female black drum spawns about 1 000 000 eggs per batch. Considering the spawning frequency estimated for the main spawning period (October–December), a female would spawn 21 times. Therefore, annual fecundity estimates for a 10 kg TW female would be about 20 million eggs. Fitzhugh et al. (1993) calculated the same number of spawns during the breeding season for black drum of the Gulf of Mexico, but they estimated that annual production could be about 32 million eggs for a 6.1 kg female. Annual fecundity estimated by Nieland and Wilson (1993) with females sampled in Louisiana ranged between 13 and 67 million eggs. In this case, BF values were similar to those obtained in the Samborombón region but the breeding season in Louisiana extends for more time (15 weeks) and spawning frequency was higher (3 days). Although annual fecundity of black drum of Samborombón was low compared with females from the Gulf of Mexico, it is one order of magnitude higher than other sciaenids inhabiting the Río de la Plata estuary, such as *M. furnieri* and *Cynoscion guatucupa* (Macchi, 1998). However, the mean RF for *P. cromis* was less than half of the average values reported for these sciaenid species (Macchi, 1998). The low RF estimated for black drum of Samborombón could be associated with the big size reached by the hydrated oocytes.

Black drum in the northern hemisphere spawn near larger sounds, bays and in estuaries (Silverman, 1979; Patillo et al., 1997; Able and Fahay, 1998). In those places, the eggs are exposed to higher salinities (between 15 and 30 psu, Joseph et al., 1964; Holt et al., 1988; Daniel and Graves, 1994) than in the more diluted waters of Samborombón Bay (8.1–17.5 psu) (Guerrero et al., 1997). The egg size of *P. cromis* in Samborombón Bay was larger than those reported for lower Chesapeake Bay: 928 μm (Joseph et al., 1964) and 1000 μm (Daniel and Graves, 1994). Large egg size in Samborombón is probably due to a higher degree of hydration needed by the egg to achieve buoyancy in the diluted waters of the bay. Thus specific gravity of the eggs would be an important trait conferring flexibility to the reproductive strategy of *P. cromis*, allowing the species to take advantage of estuarine environments as spawning grounds.

We observed that the oocyte diameter for black drum tends to decline near the end of the spawning season. A similar result was obtained when we compared the dry weight of hydrated oocytes of females collected during October (spawning peak) with samples from December. The seasonal decrease in egg size and weight during the spawning has been reported for several species. Some authors have suggested that the quality of eggs produced for the last batches could be lower than in the spawning peak (McEvoy and McEvoy, 1992; Kjesbu et al., 1996).

Previously, we mentioned that fishing pressure on black drum of Samborombón Bay has been increasing in recent years. It is a large long-lived species with a low RF that concentrates in shallow waters during spawning, where it is caught by the commercial fleet. Fishing in this area is directed towards older age classes employing bottom pair trawls. Taking this into account, future studies of black drum should include new estimates of fecundity and spawning frequency to identify possible changes in egg production associated with the increased harvest of this species.

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