Reproductive potential of the red porgy (*Pagrus pagrus*) in coastal waters of Buenos Aires Province (Argentina) and Uruguay (34º-39ºS)

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Reproductive potential of the red porgy (*Pagrus pagrus*) in coastal waters of Buenos Aires Province (Argentina) and Uruguay (34º-39ºS)

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Abstract The reproductive potential of red porgy in coastal waters of Buenos Aires Province (Argentina) and Uruguay (34º-39ºS) was studied by means of a macroscopic and histological analysis of the gonads. Length and age of first maturity were determined, and fecundity, spawning frequency and egg quality were estimated. The red porgy breeding season extends during spring and summer with a peak of main spawning between October and January. Length and age at maturity for both sexes was 24.5 cm TL and 1.54 years, respectively. Batch fecundity ranged from 6,974 (25 cm TL) to 110,725 (39 cm TL) hydrated oocytes and was fitted to a linear function of total length and ovary-free female weight. Relative fecundity ranged from 16 to 172 oocytes per female gram (ovary free). Spawning frequency was 58.5% during January 2011, indicating that females spawn once every 1-2 days at the peak of the reproductive season. These results indicate that red porgy is characterized by a low age of first maturity, partial spawning almost daily but in a bounded time period. This type of strategy may explain high recovery rates or population growth (r) as well as expanding or colonization of new areas.

Resumen Se analizó el potencial reproductivo del besugo en aguas costeras de la provincia de Buenos Aires (Argentina) y Uruguay sobre la base del análisis macroscópico e histológico de las gónadas. Se determinó la talla y edad de primera madurez sexual y se estimaron la fecundidad, frecuencia de puesta y calidad ovocitaria. Se pudo establecer que la actividad reproductiva del besugo acontece durante primavera-verano con un pico de desove principal entre octubre y enero. La estimación de la talla y edad de primera madurez para ambos sexos fue de 24,5 cm LT y 1,54 años respectivamente. La fecundidad parcial presentó un ajuste lineal con la talla y el peso de la hembra y varió entre 6.974 (25 cm LT) y 110.725 (39 cm LT) ovocitos hidratados. La fecundidad relativa osciló entre 16 y 172 ovocitos hidratados g_{-1}. Los valores de ambos parámetros presentaron diferencias interanuales. La frecuencia reproductiva, determinada mediante el uso de los porcentajes de hembras con folículos post ovulatorios, fue de 58,5% durante enero de 2011, lo que indica que los desoves ocurren una vez cada 1-2 días. Los resultados hallados indican que el besugo se caracteriza por presentar una edad de primera madurez baja (entre 1 y 2 años), desoves parciales casi diarios pero en un período de tiempo acotado. Este tipo de estrategia podría explicar tasas de recuperación o de crecimiento poblacional (r) altas como así también la ampliación de su área de distribución o la colonización de nuevas áreas.

Keywords: *Pagrus pagrus*, length at first maturity, fecundity, spawning frequency, Argentina.

Running Head: Reproductive potential of the red porgy (*Pagrus pagrus*).

Introduction

The red porgy *Pagrus pagrus* (Sparidae) is a protogynous species, which adults are typically associated with low-profile hard (live) bottom, rocky, or gravel habitats (Manooch and Hassler, 1978; Grimes *et al.*, 1982; Alekseev, 1982). This species inhabits in warm temperate to subtropical waters on both sides of the North Atlantic, including the northern Gulf of Mexico (Gulf) and Mediterranean Sea, and in the South West Atlantic from Venezuela to Argentina (Manooch and Hassler, 1978; Menezes and Figueiredo, 1985; Cotrina, 1989, Bauchot and Hureau, 1990; Vaughan *et al.*, 1992; Haimovici, 1998; Labroupoulou *et al.*, 1999; Galván *et al.*, 2009; Menezes *et al.*, 2006).

In Argentina and Uruguay, *P. pagrus* can be found in coastal waters no deeper than 75 m, mainly from 34° to 41 ° 25' S. Seasonally, this species may be also observed in the San Matías Gulf (Rio Negro) on Playa Dorada shores (41 ° 39'S), mainly between November to March and in the San Jose Gulf (42 ° 15'S) and Nuevo Gulf (42 ° 57'S) in Península Valdés (Chubut) (Galván *et al.*, 2009; García and Molinari, 2013). Ninety-four marine and freshwater fish species, belonging to 49 families, cohabit in the Buenos Aires Coastal Zone, also known as the Bonaerense Coastal Ecosystem (BCE). The BCE supports a multispecific demersal fishery, known as "variado costero", with different commercial fleet types (craft, bay or creek, coastal and off-shore). During 2015, red porgy ranked 7 th in total landings among 35 species included in the "variado costero" (Prosdocimi et al., 2016). In recent years it has represented between 5% and 6% of the whole fish community (Lagos *et al*., 2009). The commercial value of the species in the Mediterranean area and southern Spain, have made possible to consider *P. pagrus* as a species with a great potential to develop aquaculture, which has received considerable attention in recent years (Aristizabal, *et al.*, 2009).

Macroscopic staging and gonadosomatic index data suggest that the main spawning season for red porgy in the Bonaerense Coastal Ecosystem occurs between late spring and summer (Ciechomski and Cassia, 1974). During the first 2 years of life *P. pagrus* is a protogynous hermaphrodite, i.e. in the juvenile stage, it presents an ovotestis prevalence of ovarian tissue (Cotrina and Christiansen, 1994; Kokokiris *et al.*, 1999). The first maturity, both in captivity and in the wild, begins at 2 years old (Cotrina and Christiansen, 1994; Kokokiris *et al*., 1999). Since the fifth year of life, appears a balanced proportion of males and females and hermaphroditism disappears (Cotrina, 1989). Fecundity of this species has been shown to be indeterminate (Daniel, 2003). Its estimation is often difficult since most fish produce large numbers of small eggs, but it can be particularly challenging to estimate for species with indeterminate fecundity. For such species, like red porgy, fecundity is not fixed prior to the start of spawning, so oocyte counts for individual females do not accurately reflect annual fecundity. To estimate this variable in indeterminate species, the number of batches of eggs produced by a female during the reproductive season is multiplied by batch fecundity, which is the number of oocytes spawned in a single batch (Kjesbu, 2009). Typically, the number of batches is calculated as the product of spawning season duration in days and the spawning fraction (number of days between spawning events), which is estimated as the proportion of mature females that are found to possess spawning indicators, such as hydrated oocytes or postovulatory follicles, when caught during the spawning season (Murua *et al*., 2003).

Information on reproductive biology of exploited fish stocks is essential in the development of fisheries science for several reasons. For example, age or size at sexual maturity is a parameter used in most stock assessment models, directly affecting the estimation of spawning biomass and productivity. Also, the reproductive effort measured by the size or age of a species is essential in Stock–Recruitment models to understand the variability in the strength of recruitment. Other reproductive traits such as fecundity, spawning frequency and duration of the spawning season are necessary to properly estimate egg and larvae production, especially, in indeterminate fecundity species (Hunter and Macewicz, 1985). Annual changes in these variables could affect the stock productivity and produce variability in fish recruitment (Macchi *et al*., 2004). On the other hand, some reproductive variables may be associated with changes in the population structure, as size or age at first maturity, which may decline over the years as a consequence of over-exploitation (Hubold, 1978; Beacham, 1983; Trippel, 1995).

The present study provides data on the reproductive potential of red porgy in their natural environment on the basis of macroscopic and histological gonad analysis. The fact that red porgy is fishery resource intensely exploited raises the need to deepen the understanding of the biology of this species. Aim of this study is to determine size and age at sexual maturity, estimate fecundity, spawning frequency and egg quality as part of the reproductive potential of the species in coastal waters of Buenos Aires Province (Argentina) and Uruguay. This information is critical for management of marine resources and the estimate of reproductive variables may have direct application in dynamics models developed to assess populations of the species.

Material and Methods

Sample collections and histological analysis

Specimens of *Pagrus pagrus* and oceanographic data were obtained during 6 research surveys of the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP) carried out in coastal waters of Argentina and Uruguay between 2008 and 2013 (Fig. 1). Furthermore, in some years samples from commercial landings coming from Mar del Plata port became available. Table 1 shows a summary of the basic data obtained from each sampling trawl. Total length (TL) in centimeter and total weight in grams (TW) were recorded for each sampled fish. Individuals were sexed and the stage of maturity development was determined macroscopically. For this, a five-stage maturity key was employed: (1) immature; (2) developing; (3) spawning capable; (4) regressing; and (5) regenerating (Macchi and Pájaro, 2003; Brown-Peterson *et al*., 2011). In addition, the *sagittae* otoliths were collected for age determination.

For histological examinations, gonads in different maturity stages were removed after capture and preserved in 10% neutral buffered formalin (n= 1100, males and females). Fixed gonads were weighed (GW) to the nearest 0.1 g and a portion of tissue was removed from the centre of each gonad, dehydrated in ethanol, cleared in xylol and embedded in paraffin. Tissues were sectioned at approximately 4 µm thick and stained with Harri's haematoxylin followed by eosin counterstain (García del Moral, 1993).

Samples from commercial landings were used to estimate the gonadosomatic index (GSI), which was calculated as GW/TW*100 for each individual, and the mean estimated by month and sex, in order to analyze the general pattern of the reproductive cycle.

Estimation of reproductive variables

Analysis of duration of the breeding season was based on diagnosis of the maturity stages obtained by visual information and histological analysis. The variation in the monthly composition of the maturity stages was used to describe the reproductive cycle. Females were considered as reproductively active when they were capable of spawning at the time of capture or in the near future (Hunter *et al.*, 1992). Description of the stages of POF degeneration was adapted from that reported for *M. furnieri* and *M. ancylodon* of the Río de la Plata area (Macchi *et al*., 2003; Militelli and Macchi, 2004). In these species the degenerative process of the POFs was faster than that observed for other species (Hunter and Goldberg, 1980). The highest speed of degeneration was associated with the higher water temperatures in the Río de la Plata area during summer (Macchi *et al*., 2003).

The size and age at first maturity (A_{50} and L_{50}, respectively) were estimated by a logistic model by length/age class using the maximum likelihood method (Kendall and Stuart, 1967); all individual with gonad stages other than immature (1) were considered reproductive, thus the frequency of mature individuals was used as a response variable and the total length as the explanatory variable. This analysis was performed only for those years in which samples were composed by immature and mature individuals. Coefficients of the regressions obtained for males and females from the different sampled years were compared using a Chi-square test (Aubone and Wöhler, 2000).

Spawning frequency was only estimated from samples collected during the research survey carried out in January 2011, because it was the only cruise that covered the entire distribution area of the species. This variable was obtained from the incidence of females with postovulatory follicles (POFs 1), following the method described by Hunter and Goldberg (1980). To calculate the mean and coefficient of variation of this variable we used the equations developed by Picquelle and Stauffer (1985).

Batch fecundity (BF, number of oocytes released per spawning) was estimated only with samples collected during January 2011 and December 2013 by using the hydrated oocyte method (Hunter *et al*., 1985). Samples were examined histologically to determine the presence of postovulatory follicles (POFs) and hydrated oocytes. To avoid biases when estimating batch fecundity, only ovaries with hydrated oocytes and without POF0 were used (n=30 from 2011 and n=7 from 2013). Three pieces of ovary of approximately 0.1 g each were sampled from the anterior, middle and posterior section of each gonad, weighed (0.1 mg) and the number of hydrated oocytes counted. Batch fecundity was the product of the mean number of hydrated oocytes per unit ovarian weight and total ovarian weight (GW). Relative fecundity (RF, number of hydrated oocytes per gram of ovary-free body weight) was estimated as the batch fecundity divided by female weight (without ovaries). The nutritional condition was obtained for each female using the Fulton´s condition factor ($K = (TW/TL^3)*100$). The relationships between BF and the variables TL, TW (ovary-free) and K, were described using simple standard regression (Draper and Smith, 1981). Comparisons between the relationships BF versus TL obtained from different spawning seasons were based on the overlapping length ranges of females applying an analysis of covariance (Draper and Smith, 1981).

The size and weight of unfertilized eggs can tentatively be used to evaluate or estimate the overall developmental potential of eggs after fertilization. For instance, the size of egg and oil drop was sometimes considered to be beneficial for the future development of the embryo. Therefore, in order to obtain an estimate of the quality of spawning in different years, the diameter (OD), oil droplet diameter (OdD) and dry weight (DW) of hydrated oocytes were measured. For these, hydrated ovaries were selected (n=221) and samples of 100 hydrated oocytes were removed from each individual. The samples were rinsed in distiller water, dried for 24h at 60ºC and weighed (0.1 mg). The oocyte diameter and oil droplet diameter were measured for fully hydrated oocytes using an optical microscope 4x magnification and an image analyzer program (n=19).

RESULTS

Spawning period

In Figure 2 it can be observed the extension of the reproductive period of *P. pagrus* in Coastal waters of the Buenos Aires Province (Argentina) and Uruguay, based on the mean values of GSI and the percentage of males and females in reproductive activity, estimated by visual analysis. The reproductive season was relatively extensive covering spring and summer. Active females were observed between October and May with the highest percentages of spawning activity from October to January, coinciding with the highest values of GSI (Fig.2).

In addition, to confirming the macroscopic diagnosis of maturity, we estimated the proportion of actively spawning females (with hydrated oocytes and/or with post-ovulatory follicles) and also the incidence of atretic oocytes determined after histological analysis (Fig. 3). Reproductive activity of red porgy was observed between October and March, with the highest proportion of actively spawning females in December. The incidence of atretic oocytes increased from December to March, toward the end of the reproductive season, indicating the end of the spawning activity.

Length and age at first maturity

The estimates of length at first maturity (L_{50}) of *P. pagrus* obtained from samples collected during 2010 and 2013, showed highly significant differences between sexes (for 2010 $\chi2 = 7.58$, df = 1, $P < 0.01$; for 2013 $\chi^2 = 15.31$, df = 1, $P < 0.01$). L_{50} for females in 2013 was lower (24.5 cm TL) than that estimated for 2010 (26.2 cm TL). In contrast, there was not observed differences in L_{50} for males ($P > 0.05$). Figure 4 shows the logistic model obtained for 2010 and 2013. In both years, males reached first sexual maturity at smaller size than females. When we considered both sexes together, L_{50} had an average value of 24.71 cm TL for 2010 and 24.5 cm TL for 2013.

Age at first maturity (A_{50}) was only estimated for 2011. The youngest mature individual (male and female) was estimated at 1 year old. A_{50} for males was 1.31 years old (c = 1.97, n = 253) and 1.64 years (c=1.22, n = 419) for females. There was no significant difference in A_{50} between sexes (t=0.33, df=1, P>0.05). A_{50} estimated considering both sexes together was 1.54 years old.

Spawning frequency

Spawning frequency of *P. pagrus* was estimated with samples collected during the spawning peak in January 2011. Females with POF were found in the 91% of fishing hauls with positive catch of red porgy. The daily percentage of mature females with day 1 POF was 58.5% (n= 189; CV=0.6), equivalent to a spawning frequency of about 2 days for this month.

Fecundity

Batch fecundity (BF) estimated for *P. pagrus* in January 2011 ranged between 6974 (25 cm TL) and 110725 (39 cm TL) hydrated oocytes with a mean value of 37315 (±8371) hydrated oocytes. BF showed a significant linear relationship (P<0.05) with total length (TL) and total weight (TW, ovary free), a potential relationship with age and did not show relationship with the condition factor (Fig.5). In December 2013, BF values did not show any relationship with female size, weight or age but showed a significant linear relationship (P<0.05) with the condition factor, this could be due to the low number of samples (Fig. 5). BF and ranged from 7606 to 28552 hydrated oocytes, with a mean value of 13071 (± 5360) hydrated oocytes. Relative fecundity (RF) estimated with data of the two years ranged from 16 to 172 hydrated oocytes/g of female (ovary-free). Estimates of this variable showed a great dispersion and it did not demonstrate any tendency in relation to the female size and age. The mean RF estimated for 2011 (90± 15 oocytes/g) showed significant differences (P<0.05) with that obtained for 2013 (32 ±12 oocytes/g).

Size and weight of the oocytes

Diameter (OD) and dry weight (DW) of hydrated oocytes of *P. pagrus* were estimated for different months in 2010, 2011, 2012 and 2013. Mean DW showed significant differences among the four years sampled ($P < 0.05$) with an average value, estimated for a sample of 100 hydrated oocytes, of 2.55 ± 0.071 mg for 2010, 2.23 ± 0.075 mg for 2011, 1.51 ± 0.095 mg for 2012 and 2.02 ± 0.235 mg for 2013. DW did not show a significant relationship with the female size or condition (K) for 2011, 2012 and 2013, however in 2010 a significant linear relationship ($P<0.05$) was observed between DW and female total length (TL), age and weight (TW) (Fig. 6). Also, for 2011 a significant linear relationship ($P<0.05$) was observed between DW and TW.

With regard to OD, we used only 19 specimens of red porgy that showed oocytes completely hydrated. No significant relationship ($P>0.05$) were obtained between OD and the variables TL, TW and K. OD values ranged between 806 and 979 µm with a mean value of 905 ± 26 µm. The diameter of the oil droplet (OdD) ranged from 192 to 243 µm with a mean value of 215 ± 6 µm, and also no significant relationship ($P>0.05$) was observed with the maternal variables.

Discussion

The monthly analysis of gonadosomatic index (GSI) and maturity stages composition, estimated from visual information and histological diagnosis of ovaries, showed that reproduction of red porgy in coastal waters of Buenos Aires Province (Argentina) and Uruguay (34º-39ºS) occurs during spring and summer. These results are coincident to that reported by Ciechomski and Cassia (1974) and Cotrina and Christiansen (1994). In the study area, the main spawning activity of red porgy occurs between October and January, with a peak in December. Histological analysis of the ovaries also showed an increase of the atretic oocyte incidence toward March-April, which is evidence of the end of the reproductive period (Macchi, 1992).The ups and downs observed in GSI during December can be interpreted as the consequence of batch spawning or a differential in reproductive activity according to size. Cotrina (1989) analyzed the variation of ovary weight by female size during the spawning period, and suggested that larger females may complete their reproductive cycle before than the small ones.

Length at first maturity (L_{50}) estimated for *P. pagrus* in 2010 and 2013 showed significant differences between sexes and years in the case of females. Males reached first sexual maturity at smaller size than females. In 2010 the L_{50} obtained grouping both sexes (24.71 cm TL) was similar than in 2013 (24.5 cm TL). The only previous estimate of this parameter for red porgy in the Argentine Sea was obtained with samples collected in several spawning seasons between 1976 and 1982 (Cotrina and Christiansen, 1994). These authors reported an L_{50} for both sex together of about 25 cm LT, similar to those obtained in the present paper 30 years later. However, estimates of females L_{50} (26.2 cm TL in 2010 and 24.5 cm TL in 2013) were lower than those obtained in the northern hemisphere by Daniel (2003) (28.9 cm TL) and similar to those estimated by Klibansky and Scharf (2013) (25.5 cm TL).

Age at first maturity (A_{50}) estimated for *P.pagrus* was 1.54 years considering both sexes together. This value was lower than that obtained by Cotrina and Christiansen (1994) in the ZCPAU (2 to 3 years) and Kokokiris *et al*. (1999) in the Mediterranean (4 years). However, it was similar to those estimated for the same species in the southeastern US (Harris and Mcgovern, 1997; DeVries, 2006) and in the Gulf of Mexico (Hood and Johnson, 2000). A_{50} estimated for red porgy was lower than that obtained for other species in Bonaerense Coastal Ecosystem, such as Whitemouth croaker (*Micropogonias furnieri*) (A_{50} = 2.5 years, Arena and Herlt, 1983), striped weakfish (*Cynoscion guatucupa*) (A_{50} = 4 years, Vieira and Haimovici, 1997) and Brazilian flathead (*Percophis brasiliensis*) (A_{50}= 2 years, Barreto *et al*., 2011).

Daily percentage of spawning females estimated for red porgy was consistent with the values reported by Mylonas *et al.* (2004) in the Mediterranean Sea, who reported a spawning frequency between 1 and 2 days during 2001-2002 spawning season. These estimates of daily percentage of spawning females were higher to those reported for *M.furnieri* (between 3 and 5 days; Macchi *et al*, 2003), *C.guatucupa* (between 6 and 8 days; Militelli *et al*., 2013) and *P.brasiliensis* (6 days; Militelli and Macchi, 2001).

Batch fecundity (BF) obtained for 2011 was a linear function of total length and ovary-free body weight and a power function of age. In 2013, BF values did not show any relationship with female size. Mean BF obtained for both years was 37315(±8371) and 13071 (± 5360) hydrated oocytes respectively. Relative fecundity values ranged from 16 to 172 hydrated oocytes/g of female (ovary-free) and no showed significant relationships with the female size, weight, age or the condition factor (K). Mean values of RF were similar to those obtained for whitemouth croaker, striped weakfish and Argentine croaker (*Umbrina canosai*) (Militelli *et al*., 2013) and lower than those obtained for Brazilian flathead (319 ± 129 oocytes / g for 1999; Militelli and Macchi, 2001).

There are few studies on *P.pagrus* fecundity so far that consigned estimates of this parameter in particular. This is because obtain hydrated females is usually a rare occurrence. Some previous studies on red porgy fecundity were made with females in advanced maturation stage (with yolked oocytes), prior to oocyte hydration. In these cases, the counting of yolked oocytes at early spawning season was considered an estimate of the absolute or potential fecundity. Ciechomski and Cassia (1974) and Klibansky and Scharf (2013) have conducted studies on the reproductive biology of this species, however, fecundity data are not comparable with those of the present paper, because they counted all oocytes batches since the beginning of vitellogenesis.

The hydrated oocytes diameter (OD) ranged between 788 and 1028 μm and the oil droplet (OdD) between 185 and 239 μm. These variables did not show significant relationships with the female size, age or condition factor K. The hydrated oocytes dry weight showed differences among the four sampling years. The mean highest value for a sample of 100 hydrated oocytes was 2.55 ± 0.071 mg obtained for 2010, moreover a significant linear relationship between the dry weight and female size was observed only for this year. The lowest value was estimated in 2012, 1.51 ± 0.095 mg, but we obtained fewer samples during this year with. Values of OD and OdD were coincident with those previously reported for this species both in wild and in captivity (Cardenas and Calvo, 2003; Marchinandiarena *et al*., 2003; Radonic *et al*., 2005). These results suggest that hydrated oocytes sampled in 2010 had a greater amount of reserves, suggesting an egg quality higher than in other years analyzed. In general, the size of hydrated oocytes in red porgy was similar to that found in *M.furnieri*, *C.guatucupa*, *U.canosai* (Militelli *et al*., 2013) and *P.brasiliensis* (Militelli, 1999), but the oocyte dry weight estimated for the last one was lower (1.70 ± 0.12 mg to 100 oocytes for 2003) (Rodrigues *et al*., 2007).

The species life cycle characteristics are important factors in the population performance. The population growth rate depends directly upon fecundity, survivorship, and timing of reproduction. Averaged over many generations, the three parameters must balance, or the population eventually will decline to extinction or grow exponentially (Winemiller, 2006). This author proposed three endpoint strategies result from trade-offs among age of maturation (positively correlated with mean generation time), fecundity, and survivorship. The periodic strategy corresponds to high values on the fecundity and age at maturity (the latter a correlate of population turnover rate) and low values on the juvenile survivorship. The opportunistic strategy of high r (via rapid maturation) corresponds to low values on all three parameters. The equilibrium strategy corresponds to species with low fecundity values and high values in age at maturity and juvenile survivorship. Red porgy presents an age at first maturity less than two years and spawning almost daily partial but in a limited period of time to spring - summer. This type of strategy adopted could correspond to an opportunistic strategy which would explain high recovery rates of population growth (r) as well as expanding its range or colonization of new areas (Garcia and Molinari, 2013).

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Figure 1. Locations where samples of red porgy (Pagrus pagrus) were collected during the research surveys carried out in coastal waters of Argentina and Uruguay between 2008 and 2013.

Figure 2. Mean values of gonadosomatic index (GSI) and monthly frequency (percentage) of active males (M) and females (F) of P. pagrus.

Figure 3. Monthly frequency (proportion) of red porgy females with hydrated oocytes, post-ovulatory follicle (POF) and atretic oocytes.

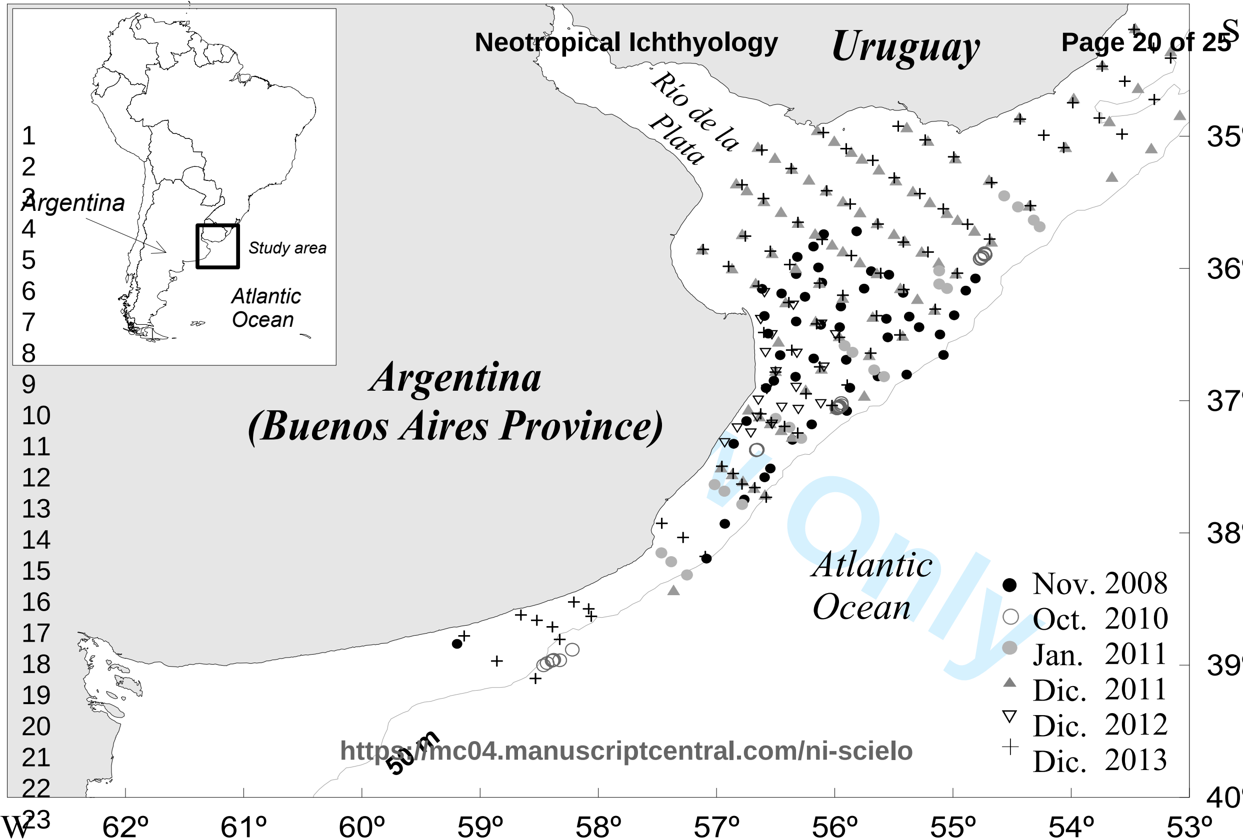
Figure 4. Logistic model fitted to the proportion of mature individuals by length class estimated for males (black line), females (gray line) and the both sexes together (scripts) of red porgy, with samples collected in 2010(A) and 2013 (B).

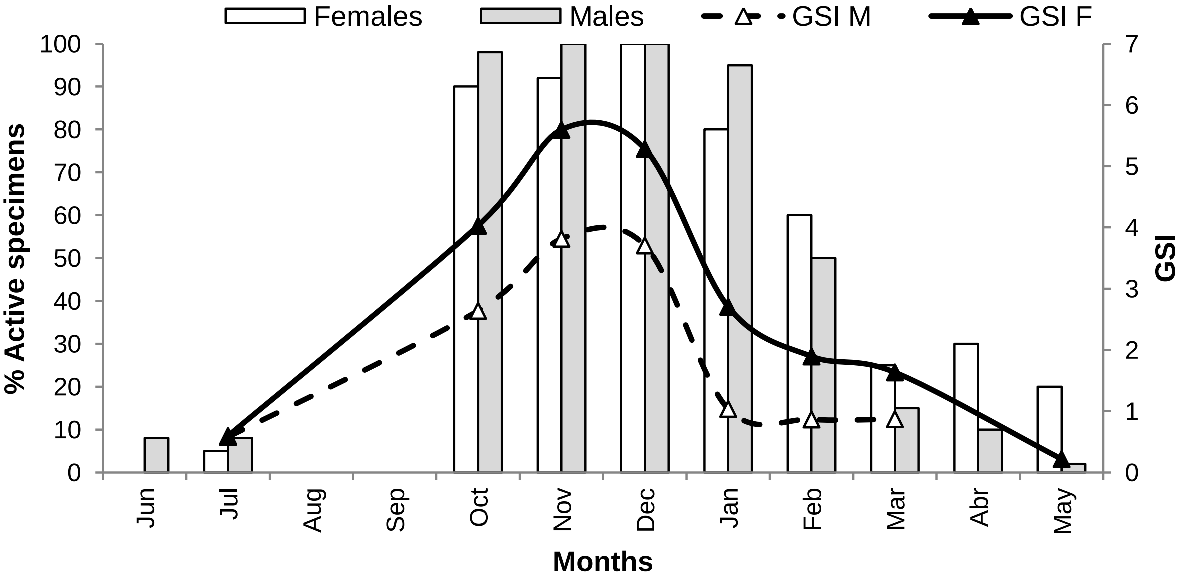
Figure 5. Relationships: (A) Batch fecundity (BF) vs Total length, (B) BF vs. Total weight (without ovary) (TW) and (C) BF vs age and (D) BF vs condition factor obtained for red porgy in 2011 (cross) and 2013 (circles).

Figure 6. Relationship between oocyte dry weight and: (A) Total length; (B)Total weight (without ovary); (C) Age in years ; (D) Condition factor for P. pagrus. Gray squares: 2010; cross: 2011; black triangles: 2012 and circles: 2013.Gray line: 2010 and black line: 2011.

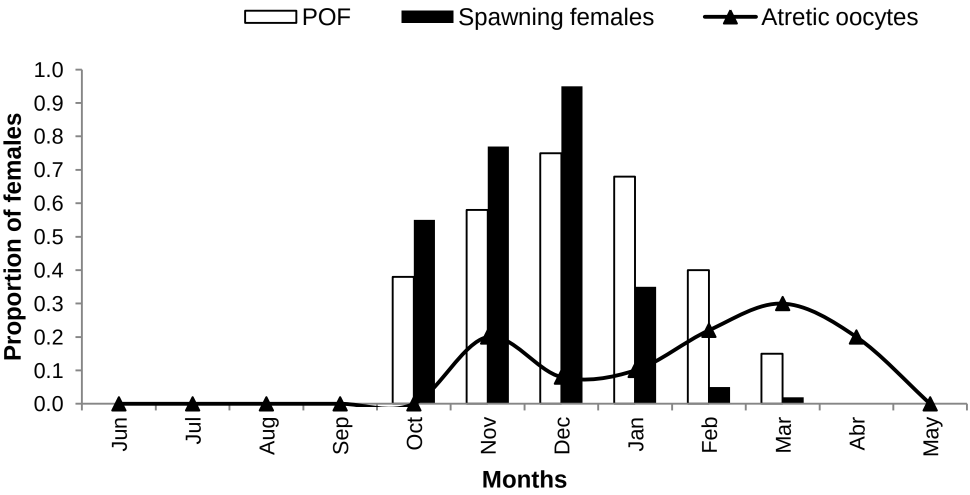
Table 1: Date, number and total length of P. pagrus sampled during 6 research surveys and 5 years commercial landings carried out between 2008 and 2013.

	Year	Period	Number of samples	Total length range (cm)
Research survey	2008	03/11/08 to 23/11/08	191	16-50
	2010	18/10/10 to 26/10/10	249	21-48
	2011	10/01/11 to 16/01/11	496	21-47
	2011	24/11/11 to 05/12/11	503	12-58
	2012	07/12/12 to 19/12/12	412	16-49
	2013	05/12/13 to 19/12/13	619	8-50
			Total: 2470	
Commercial landings	2009	23/03/09 to 12/11/09	292	18-48
	2010	11/01/10 to 06/12/10	364	16-50
	2011	21/02/11 to 05/12/11	146	18-52
	2012	24/01/12 to 21/11/12	225	11-50
	2013	13/01/13 to 27/10/13	54	20-44
			Total: 1081	

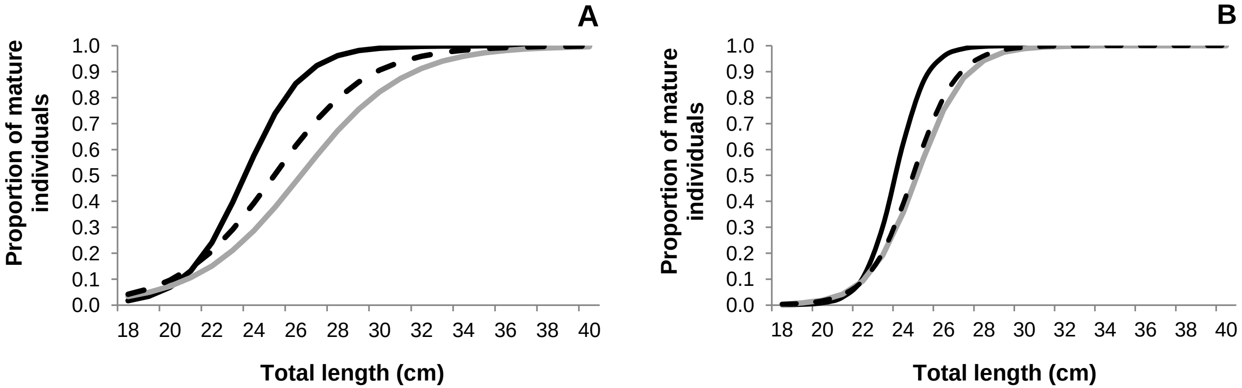

Uruguay
Río de la Plata
Argentina
Study area
Atlantic Ocean
Argentina
(Buenos Aires Province)
Atlantic Ocean
Nov. 2008
Oct. 2010
Jan. 2011
Dic. 2011
Dic. 2012
Dic. 2013
50 m
S
35º
36º
37º
38º
39º
40º
W
62º
61º
60º
59º
58º
57º
56º
55º
54º
53º

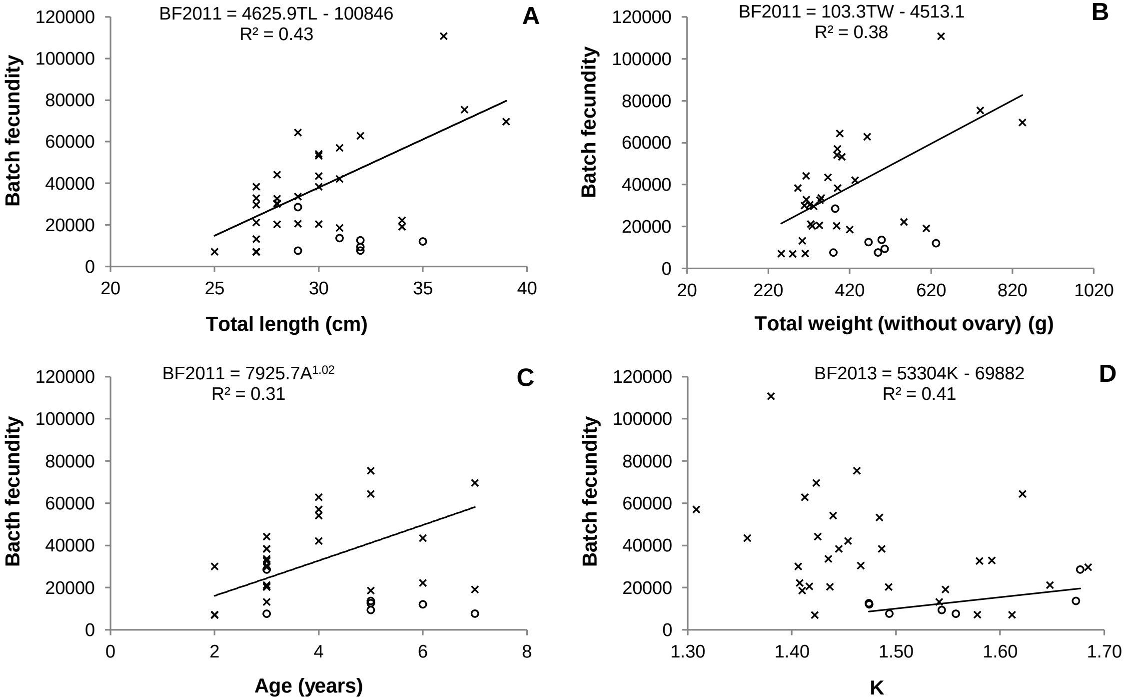


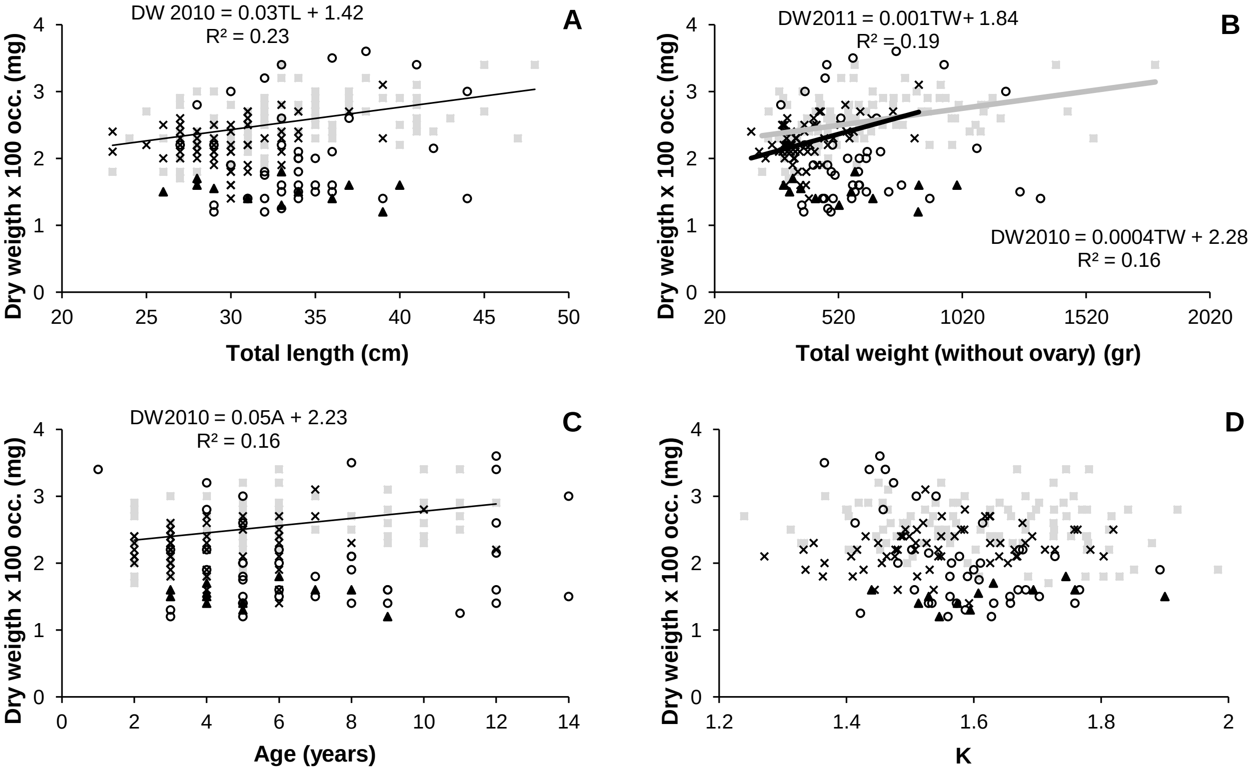
Females
Males
GSI M
GSI F
% Active specimens
GSI
Months
100
90
80
70
60
50
40
30
20
10
0
7
6
5
4
3
2
1
0
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Abr
May



POF
Spawning females
Atretic oocytes
Proportion of females
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Abr
May
Months


A
Proportion of mature individuals
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
18 20 22 24 26 28 30 32 34 36 38 40
Total length (cm)
B
Proportion of mature individuals
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
18 20 22 24 26 28 30 32 34 36 38 40
Total length (cm)


BF2011 = 4625.9TL - 100846
R² = 0.43
A
Batch fecundity
Total length (cm)
BF2011 = 103.3TW - 4513.1
R² = 0.38
B
Batch fecundity
Total weight (without ovary) (g)
BF2011 = 7925.7A1.02
R² = 0.31
C
Batch fecundity
Age (years)
BF2013 = 53304K - 69882
R² = 0.41
D
Batch fecundity
K
0
20000
40000
60000
80000
100000
120000
20
25
30
35
40
220
420
620
820
1020
2
4
6
8
1.30
1.40
1.50
1.60
1.70



A
DW 2010 = 0.03TL + 1.42
R² = 0.23
Dry weigth x 100 occ. (mg)
Total length (cm)
B
DW2011 = 0.001TW+ 1.84
R² = 0.19
DW2010 = 0.0004TW + 2.28
R² = 0.16
Total weight (without ovary) (gr)
C
DW2010 = 0.05A + 2.23
R² = 0.16
Age (years)
D
K