# FIRST DATA ON THE AGE AND GROWTH OF BRAZILIAN FLATHEAD *Percophis brasiliensis* (PISCES: PERCIFORMES) IN SAN MATÍAS GULF, NORTHERN PATAGONIA (ARGENTINA)

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**ABSTRACT.** Brazilian flathead *Percophis brasiliensis* is a commercially important perciform fish caught as bycatch by trawlers throughout its latitudinal distribution range (from 23° S in Brazil to 47° S in Argentina). It is associated with the catches of Argentine hake *Merluccius hubbsi* and Patagonian red shrimp *Pleocticus muelleri* in San Matías Gulf (SMG). The main objective of this study was to describe the first data on the growth of this species in SMG and to compare the results with available information for other areas of the Argentine Continental Shelf (ACS). The study was carried out using 294 specimens (196 females, 97 males and one of indeterminate sex) collected over four non-consecutive years from commercial/recreational fishing and during research cruises. The age of individuals was determined by reading and counting opaque-hyaline rings on the *sagittae* otoliths. The maximum ages observed were 14 years for females and 12 years for males. Growth parameters were estimated using the von Bertalanffy mode. Significant differences in $L_\infty$ parameter between sexes were found ($L_\infty$ males = 54.58 cm; $L_\infty$ females = 78.31 cm, $p < 0.05$). Growth parameters were different from those determined in previous studies for the ACS.

**Key words:** Age determination, growth curve, *Percophis brasiliensis*, gulf region, poor-data species.

## INTRODUCTION

Studies dealing with the age determination and growth of fish species are considered a crucial topic in fisheries research (Hoenig and Gruber 1990; Officer et al. 1996; Campana 2001), since they provide basic information for stock assessment (Gallagher and Nolan 1999).

Brazilian flathead *Percophis brasiliensis* Quoy and Gaimard 1825 (Suborden Trachinoidei) is a coastal fish species of demersal-benthic habits. Its distribution extends from 23° S (Rio de Janeiro, Brazil) to 47° S (north of Santa Cruz Province, Argentina), and from the coast down to depths of 75 m (Cousseau and Perrotta 2013). *P. brasiliensis* is mainly caught by bottom trawl nets in the context of a multi-species fishery in the coastal ecosystem of Buenos Aires Province (CEB) on the Argentine Continental Shelf (ACS) (Carozza et al. 2001). Several studies on the composition of catches and growth were carried out in this area (Carozza et al. 2018; Rico et al. 2018). This species mainly inhabits the northeast area of San Matías Gulf (SMG) between the coastline and the 90 m isobath (López et al. 2012). It is caught as bycatch in a multispecific fishery targeting Argentine hake *Merluccius hubbsi* (Romero et al. 2013) and in a recent fishery targeting Patagonian red shrimp *Pleoticus muelleri* (Sepúlveda 2018). Landings recorded since the early 90s have always amounted to a few tons (8.75 ± 21.92 SD), except for a peak recorded for the period 1999-2000 (82.3 ± 33.66 SD).

At present, Brazilian flathead is considered a data-poor species in SMG. Biological information on *P. brasiliensis* in SMG fishery is scarce and insufficient for inferring the status of its population structure and dynamics. However, some biological aspects of this species were previously studied in the CEB, where the peak of reproductive activity was observed in November and gonads in resting stage were detected in May, June, and August (Rodrigues et al. 2010, 2013). *P. brasiliensis* is a long-living, slow-growing species with maximum ages ranging from 15 years for females to 19 years for males (Rico and Sáez 2010; Barretto et al. 2011; Sáez et al. 2011). Differential growth between the sexes from the first year of life has been observed with females reaching greater sizes than males of the same age (Barretto et al. 2011). Despite their longevity, females mature in the second year (35.6 cm total length, TL) and males in the first (25.5 cm TL) (Rodrigues 2012). The chemical composition of otoliths also highlighted a possible difference between individuals belonging to SMG and the Argentine-Uruguayan Common Fishing Zone (AUCFZ) (Braicovich and Timi 2008; Avigliano et al. 2015). This evidence may indicate that *P. brasiliensis* in SMG could be a relatively isolated subpopulation or stock, as observed for other species of similar latitudinal distribution range, such as Argentine hake *M. hubbsi* (Sardella and Timi 2004; Ocampo Reinaldo et al. 2013) and the Brazilian sandperch *Pinguipes brasilianus* (Timi et al. 2008).

The aim of this study was to determine first data on the age and growth parameters of *P. brasiliensis* in SMG as an initial step towards understanding basic aspects of the biology and population dynamics of this species and its role in demersal and coastal fish assemblages.

## MATERIALS AND METHODS

Samples were collected over four non-consecutive years from three sources: research cruises, commercial landings and coastal rod fishing (Table 1). Total length (TL) to the nearest cen-

Table 1. Source and number of samples. RC: research cruises, CL: commercial landings from the Patagonian red shrimp and the Argentine hake fisheries, RF: rod fishing.

| Month | 2009 | 2011 | 2013 | 2014 |
|---|---|---|---|---|
| February | - | - | - | 3 (CL) |
| March | - | - | - | 18 (CL) |
| April | - | - | - | 5 (CL) |
| May | 25 (CL) | - | - | - |
| June | 17 (CL) | - | 3 (CL) | - |
| August | 14 (CL) | - | - | - |
| November | 200 (RC) | 9 (RF) | - | - |
| Total | 256 | 9 | 3 | 26 |

timeter, total weight (TW) in grams and sex were recorded for each fish. *Sagittae* otoliths were extracted and one otolith from each pair was washed, dried and embedded in opaque epoxy resin. The otoliths were sectioned transversally through the nucleus region in order to obtain a 0.5 mm-thick section using a Maruto MC-201 microcutter.

### Age validation

In order to validate the periodicity of the growth rings, the type of band (opaque-translucent) on the edges in the otolith sections was recorded.

### Age determination

To determine the age of the individuals, the pairs of opaque-translucent bands in the otolith sections were counted by two independent readers under incident and transmitted light using a stereomicroscope at 40X magnification (Figure 1). Age was determined to the nearest lower according to Barretto et al. (2011) without knowledge of the length and sex of the specimen, considering that one opaque and one translucent band representing one year of the fish life. The average percent error (APE) (Beamish and Fournier 1981) and the coefficient of variation (CV) (Chang 1982) were used to validate the age determination of both observers.

### Growth

The von Bertalanffy (1938) growth model (VBGM) was used to characterize the growth in length as a function of age using the following equation:

$$TL_t = L_\infty (1 - e^{(-k(t-t_0))}) + E_t$$

where $TL_t$ is the average total length (cm) at age $t$

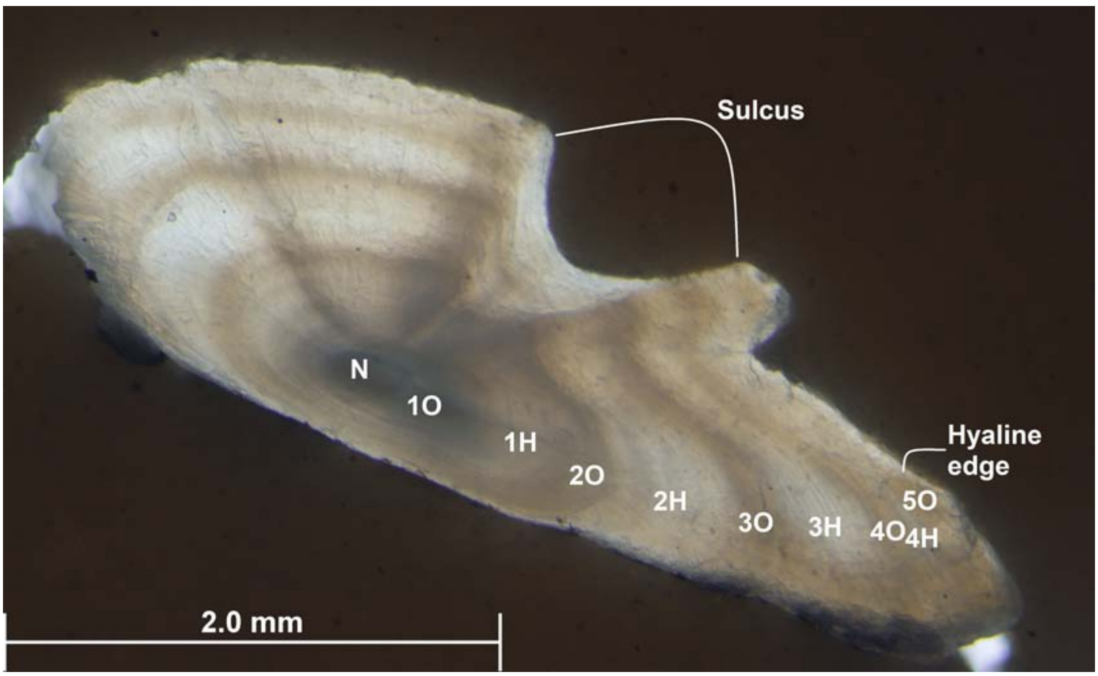


Figure 1. Thin section of the *saggitae* otolith of a 4-years-old female *Percophis brasiliensis*. N: nucleus, O: opaque band, H: hyaline band; the numbers refers to the annual rings.

(years), $L_\infty$ is the maximum total length (cm), $k$ is a growth rate parameter (year$^{-1}$), $t_0$ is the theoretical age (years) at zero length and $E_t$ with Normal distribution since we were working with averages $TL_t$.

The model was fitted using the generalized least squares method (Kimura 1980). Growth parameters ($L_\infty$, $k$ and $t_0$) were estimated using the maximum likelihood method (Cerrato 1990). Comparisons between growth curves of both sexes were carried out using the likelihood ratio and the $\chi^2$ distribution ($p < 0.05$; Cerrato 1990).

## RESULTS

### Age determination

Age was determined for a total of 294 individuals (196 females, 97 males and one undefined). The average percent error (APE = 0.28%) and the coefficient of variation (CV = 0.40%) indicated that the criteria for age determination was consistent across the readers (Cerrato 2000).

TL values ranged from 33 to 71 cm for females and 32 to 63 cm for males. Both sexes showed unimodal frequency distribution at 55 cm for females and 50 cm for males (Figure 2).

### Age validation

Both bands (opaque and hyaline) were present in most of the months analyzed (Figure 3). The opaque band was frequent in February, although deposition could have started months earlier. In addition, the hyaline ring was deposited from March to August.

### Growth

Ages ranged from 2 to 14 years for females and 3 to 12 years for males, with a mode of 4-year-old specimens in both sexes (Figure 4; Table 2). The VBGM showed a good fit to the observed data with females larger than males at the same age (Figure 5). When comparing the three parameters together ($L_\infty$, $k$, $t_0$), significant differences were found ($p < 0.05$) between the growth curves by sex. Comparisons of the parameters individually detected significant differences for the asymptotic length only (Table 3).

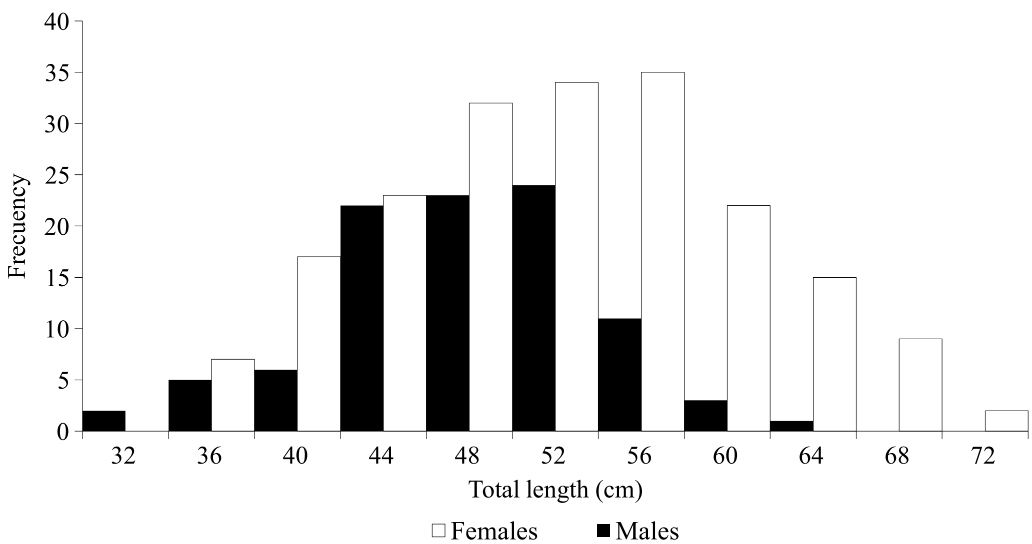


Figure 2. Frequency distribution of total length by sex of *Percophis brasiliensis*.

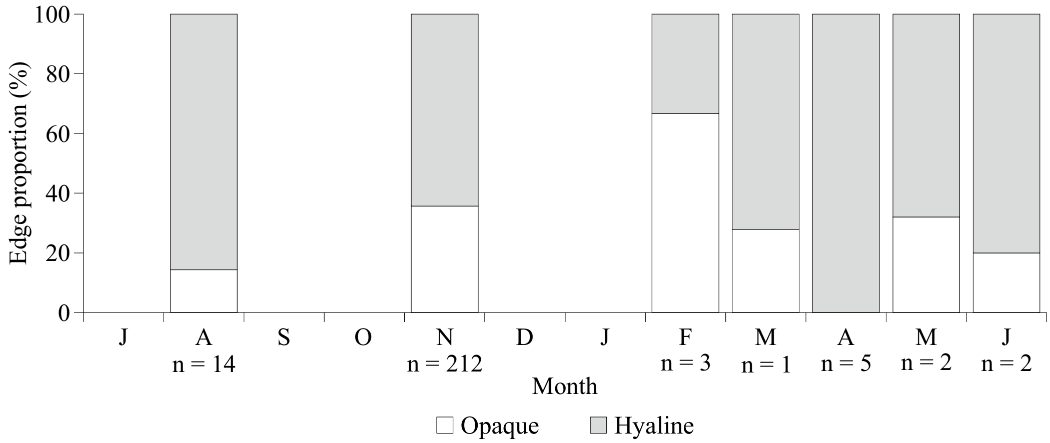


Figure 3. Monthly percentage of opaque and hyaline edges in whole otoliths of *Percophis brasiliensis* in SMG.


Figure 4. Frequency distribution of age by sex of *Percophis brasiliensis*.

## DISCUSSION

The accuracy of age readings and the low percentage of otoliths discarded due to malformations show that the *sagittae* otoliths of *P. brasiliensis* appear to be suitable for reading ages, like most *sagittae* otoliths of temperate-water fish (Panella 1974; Pauly 1980; Lombarte and Lleonart 1993; Morales-Nin 2000). In all the thin sections analyzed the nature of the first ring was opaque, coinciding with observations for the same species on Buenos Aires coast (Barretto et al. 2011). This could be because the opaque band is formed in the warm months (late spring and summer) when recruitment of individuals to the populations of *P. brasiliensis* on the Argentine coast is recorded (Rodrigues 2012). On the other hand, the hyaline ring corresponds to the coldest seasons (autumn and winter). Although the validation was carried out by mixing months of dif-

Table 2. Range (cm), mean total length (TL, cm) per age (in years) of females, males and pooled data of *Percophis brasiliensis* from SMG. SD: standard deviation.

| | General | | Females | | Males | |
|---|---|---|---|---|---|---|
| Age | Range | Mean TL ± SD (n) | Range | Mean TL ± SD (n) | Range | Mean TL ± SD (n) |
| 2 | 35-43 | 37.6 ± 2.97 (8) | 35-43 | 37.6 ± 2.97 (8) | | - |
| 3 | 32-48 | 40 ± 3.85 (26) | 35-48 | 40.9 ± 3.55 (22) | 32-46 | 39 ± 4.11 (16) |
| 4 | 33-53 | 44.7 ± 3.84 (66) | 33-53 | 45.2 ± 3.92 (45) | 34-49 | 43.5 ± 3.47 (21) |
| 5 | 35-56 | 48.1 ± 4.26 (49) | 39-56 | 49.4 ± 3.78 (33) | 35-54 | 45.6 ± 4.15 (16) |
| 6 | 42-61 | 51.3 ± 4.24 (40) | 45-61 | 53.5 ± 3.44 (24) | 42-53 | 48.2 ± 3.25 (16) |
| 7 | 49-63 | 54.7 ± 3.77 (19) | 51-60 | 55.8 ± 2.59 (12) | 49-63 | 52.7 ± 4.82 (7) |
| 8 | 47-65 | 55.8 ± 4.71 (23) | 52-65 | 58.4 ± 3.58 (15) | 47-53 | 51 ± 1.85 (8) |
| 9 | 52-70 | 59.2 ± 4.60 (26) | 54-70 | 60.6 ± 4.08 (20) | 52-54 | 53.4 ± 0.89 (5) |
| 10 | 52-67 | 58.6 ± 4.94 (13) | 55-67 | 60.3 ± 4.92 (9) | 52-57 | 54.75 ± 2.06 (4) |
| 11 | 51-67 | 60.1 ± 5.25 (8) | 59-67 | 63.2 ± 3.27 (5) | 51-57 | 55 ± 3.46 (3) |
| 12 | 51-61 | 56 ± 7.07 (2) | | 61 (1) | | 51 (1) |
| 13 | | 71 (1) | | 71 (1) | | - |
| 14 | | 68 (1) | | 68 (1) | | - |

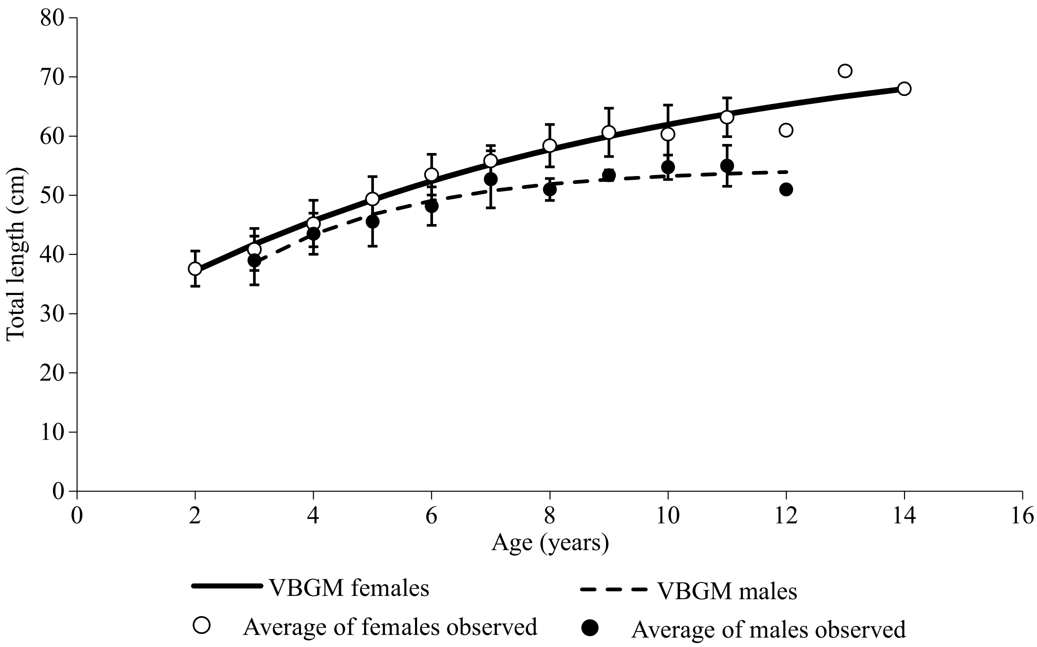


Figure 5. Growth curves of *Percophis brasiliensis* by sex from San Matías Gulf. Bars represent standard deviation. VBGM: von Bertalanffy growth model.

Table 3. von Bertalanffy's growth parameters ($L_\infty$, $k$, $t_0$) for *Percophis brasiliensis* from San Matías Gulf. The general curve includes one individual of indeterminate sex shown as comparison purpouses with other studies.

| | $L_\infty$ (cm) | $k$ (year$^{-1}$) | $t_0$ (years) | N |
|---|---|---|---|---|
| General | 86.06 | 0.08 | -5.51 | 294 |
| Females | 78.31* | 0.11 | -3.61 | 196 |
| Males | 54.58* | 0.36 | -0.46 | 97 |

*Indicates significant differences ($p < 0.05$).

ferent years without having the entire cycle and with few individuals in some months, the periods of growth ring formation coincided with those reported by Barretto et al. (2011) for individuals from Buenos Aires coast. Similarly, the formation of rings at similar times for fish that inhabit Southwestern Atlantic coast has been described. Scartascini et al. (2015) studying the seasonality of the otoliths of the white croaker *Micropogonias furnieri* in SMG reported the deposition of opaque bands between November and January, coinciding with that reported for weakfish *Cynoscion guatucupa* (López Cazorla 2000) in Bahía Blanca waters and for wreckfish *Plyprion americanus* in southern Brazil (Peres and Haimovici 2004).

Considering that the first pair of rings are usually harder to identify than the subsequent pairs, some authors have suggested not counting it (Peres and Haimovici 2004). In order to compare the estimates made, this study used the criteria described by Barretto et al. (2011) to estimate the age of the species in another site of its distribution.

The maximum ages observed in this study (14 years for females and 12 for males) were higher than the maximum ages previously recorded in CEB for this species: 6 years (Tomo 1969), 7 years (San Román 1974) and 12 years (Perrotta and Fernández-Giménez 1996). However, they were lower than those recorded by Barretto et al. (2011): 15 years for females and 19 years for males (both between 60 and 70 cm TL). Individuals belonging to the 0 and 1 year age classes were not represented in this study even though the trawl nets used during the research cruises had a small mesh (40 mm) inner cover. Other studies carried out in CEB also reported the absence or low occurrence of individuals belonging to these year classes (Rico et al. 2018). Considering that small individuals inhabit mainly shallower areas (Barretto 2007) their presence would not have been detected in this study because these areas were not sufficiently surveyed.

The VBGM was adequate for describing the growth of *P. brasiliensis*. Differential growth between sexes was observed in this study with females larger than males at the same age as described previously by San Román (1974) and Barretto et al. (2011). *P. brasiliensis* is a slow growing, relatively long-lived species like other perciform fishes studied in SMG (Rubinich and González 2001; González 2006).

The estimated $L_\infty$ for females (78.31 cm TL) was higher than that previously reported (65.2 and 63.5 cm TL) in the northern area of distribution (CEB) (Barretto et al. 2011), while $L_\infty$ for males (54.58 cm TL) was lower than the estimated for the species outside the SMG (58.1 cm and 58.7 cm TL, Barretto et al. 2011). Although habitat differences between the two areas (Warm Temperature Southwestern Atlantic province versus the "Magellanic Province") (Spalding et al. 2007) might affect the growth of these species, differences in $L_\infty$ could also be partially linked to the quality of the data since Barretto et al. (2011) used a wider range of age classes in their study (17 age classes versus 14 in this study). In our study, the lack of individuals smaller than 33 cm TL might explain the relatively high values of $t_0$ and consequently have an effect over the grow rate parameter ($k$). However, differences in TL between males and females within SMG population compared to other stocks were clear. Differences could also be explained by the different fishing intensity to which the population of Brazilian flathead has been subjected at both sites (CEB and SMG). The CEB fishery began around 1960 and catches increased up to 8,350 t in 1997. Although catches have decreased since then, more than 7,000 t of Brazilian flathead are still landed in CEB (Rico et al. 2018). The intensity and long-term fishing pressure of the CEB fishery could have caused the removal of adult individuals resulting in a greater relative abundance of individuals between 3 and 5 years old (Rico et al. 2018).

The estimated $k$ (0.11 year$^{-1}$) and $t_0$ (-3.61 years) for females were lower than those calculated previously for Buenos Aires stock by Barretto et al. (2011) ($k$ = 0.29 year$^{-1}$ in spring and 0.26 year$^{-1}$ in winter, $t_0$ = -1.15 years in spring and -2.01 years in winter). However, if data from smaller (< 33 cm TL) and larger individuals (> 70 cm TL) were added to the VBGM the estimated value of $t_0$ could be lower, leading to a higher value of $k$. On the other hand, parameters of the VBGM in males showed more realistic values due to an asymptote of TL seems to be reached ($L_\infty$ is similar to maximum TL). In this sense, the estimated values of $k$ (0.43 year$^{-1}$) and $t_0$ (-0.36 years) for males were higher than those previously calculated for individuals from Buenos Aires stock by Barretto et al. (2011) ($k$ = 0.26 year$^{-1}$ in spring and 0.21 year$^{-1}$ in winter, $t_0$ = -2.02 years in spring and -2.90 years in winter). Since $L_\infty$ and $k$ are intimately related, the differences found in $k$ from this study could also be a consequence of females reaching larger size in SMG, while males reached smaller size as mentioned above. This caused a decrease in the value of $k$ for females and an increase in the value for males.

Taking into account the ages determined in our study and the age at maturity (1.6 years for males and 2.7 years for females) identified by Rodrigues (2012), the differential growth for each sex could be explained by the fact that once sexual maturity is reached the growth rate decreased (Brett 1979). In this way, females only begin to use part of their energy for reproduction during the second year of life and have a one-year advantage over males to increase their size (Barretto et al. 2011). Differences in growth could also be determined by changes in environmental conditions, water temperature and food availability, which could affect metabolic rates (Dutil et al. 1999). The different growth rates may also be a consequence of changes in the genetic characteristics of the stocks (Renzi et al. 2009).

This work describes for the first time the growth of *P. brasiliensis* in SMG and shows differences with previous studies of this species from other areas of the Argentine continental shelf. In agreement with other authors (Braicovich and Timi 2008; Braicovich and Timi 2010; Rodrigues et al. 2010; López et al. 2012; Avigliano et al. 2015; Braicovich et al. 2016), these preliminary results provide data that suggest that the population of *P. brasiliensis* from SMG constitutes a different stock from those in CEB and the Argentine-Uruguayan Common Fishing Zone (AUCFZ). In this respect, defining stocks as discrete units is useful for stock assessment and to propose management measures (Ihssen et al. 1981). Future studies on stock evaluation of *P. brasiliensis* in SMG should contemplate appropriate methodologies for data-poor species (Jiao et al. 2011). Determining biological parameters that could limit and control the management of fisheries is not an easy task, however it is essential to understand as much as possible about the resource in order to ensure that its activity is sustainable in all aspects: the stock in question, the community it inhabits and the society that depends on the resource for its livelihood.

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