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## ORIGINAL INVESTIGATION

### Growth and age at sexual maturity of South American sea lions

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#### Abstract

The average age at sexual maturity (*ASM*) is an important parameter for evaluating the reproductive potential or status of a population. South American sea lions, *Otaria flavescens* in Patagonia (Argentina) were exploited and reduced to less than 10% of pre-exploitation numbers. At present, the population is recovering at a rate of 6%. In this paper, we studied growth and age at sexual maturity of South American sea lions in the south-western south Atlantic by examining 219 individuals (females and males) collected between 1989–2008. Individuals were aged by counting growth layer groups in tooth sections, standard body length was measured and male and female reproductive organs were examined macroscopically and histologically to establish individual sexual maturity. Maximum recorded length for males and females was 264 cm and 200 cm, respectively, and maximum ages 19 and 21 yrs. *ASM* defined as the age where 50% of females are mature, was estimated at  $4.8 \pm 0.5$  years old, corresponding to a mean SL of 147 cm, about 81% of their asymptotic length. First observed ovulation occurred during the 4th year, first birth may occur between 4 and 5 years old. Males physiologically mature between 4–6 years, but the size of the testes shows that all males became sexually mature by the age of 9 years when they reach a mean SL of 212 cm, about 86% of their asymptotic body length. The present information on *ASM* and growth of *O. flavescens* will improve the development of population dynamics models, to investigate the impact of recovering sea lions populations on its marine environment, as well as its trophic interactions with commercial fisheries.

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**Keywords:** *Otaria flavescens*; Average age at sexual maturity; Body growth; Patagonia

#### Introduction

The average age at sexual maturity (*ASM*) can vary widely among pinnipeds (Riedman 1990), and has been described as an important criterion for evaluating the reproductive potential or status of a population (Eberhardt and Siniff 1977; DeMaster 1978, 1981; York 1983). This life-history parameter together with

longevity is important for the estimation and interpretation of population size, age structure, and growth (York 1987; Wickens 1993). Although reproductive parameters have been established for some populations, it should be emphasized that there is considerable variation between populations or with latitude, and within single populations there may be changes with time (Laws and Sinha 1993). The *ASM* can drop after a population has been reduced by intensive commercial hunting, as was the case for northern fur seals, harp seals, southern elephant seals (Riedman 1990; Pistorius et al. 2001), and Antarctic fur seal (Lunn et al. 1994). On a smaller scale

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*ASM* can vary among breeding colonies depending on colony age and density (Riedman 1990). For example, southern elephant seals exhibited higher *ASM* in both sexes in unexploited high-density colonies, while new breeding areas of northern elephant seals were colonized by young males and females that start to breed earlier (Riedman 1990). Furthermore, within the same colony females that breed earlier are probably the healthiest and largest of their cohort (Reiter et al. 1981). This suggests that seals need to reach a minimum level of growth before maturity. Body growth reflects a complex integration of a physical and environmental processes, thus growth models allow comparisons between sexes, populations, and species (Winship et al. 2001). They also are important components of bioenergetic models, which are often used to assess food requirements.

South American sea lion, *Otaria flavescens*, is presently distributed along the South American coast, from Torres, Brazil (29°20'S; 49°43'W) (Rosas et al. 1994) to Zorritos (4°S) in Peru (Riedman 1990). Commercial harvesting during the early 20th century decimated populations throughout the Atlantic coast (Videla 1980; Crespo and Pedraza 1991; DINARA 2006). Responses to this dramatic change varied by geographic area. Some populations are still decreasing (Venegas 2001; Soto et al. 2004; Bartheld et al. 2006; Páez 2006), some are recovering slowly (Thompson et al. 2005; Sepúlveda et al. 2006), and since 1990 some have been recovering and recolonizing areas at different growth rates (Reyes et al. 1999; Dans et al. 2004; Schiavini et al. 2004; Grandi et al. 2008). Despite their large abundance, our understanding of the population demographics of South American sea lions is limited by a lack of data, including age at first reproduction and growth. Although there are some studies on gonadal activity (Murie 1872; Hamilton 1934, 1939) and body growth (Rosas et al. 1993), information on the age and length at sexual maturation of animals is limited.

Currently, there is particular interest in developing population dynamics models for sea lion populations in order to investigate the impact of recovering populations on their marine environment and their trophic interactions with commercial fisheries (e.g., Butterworth et al. 1995; Guinet et al. 1996; Koen-Alonso and Yodzis 2005) and to evaluate different scenarios of population decline (Pascual and Adkison 1994; Trites and Donnelly 2003; Towell et al. 2006). Some of the essential parameters to the development of such models are data on population biomass, sex- and age-specific growth rates, and age at sexual maturity.

The aims of this study were to estimate *ASM*, and to assess parameters of body growth of the population of South American sea lions to assist the authorities for the conservation and managements of the species.

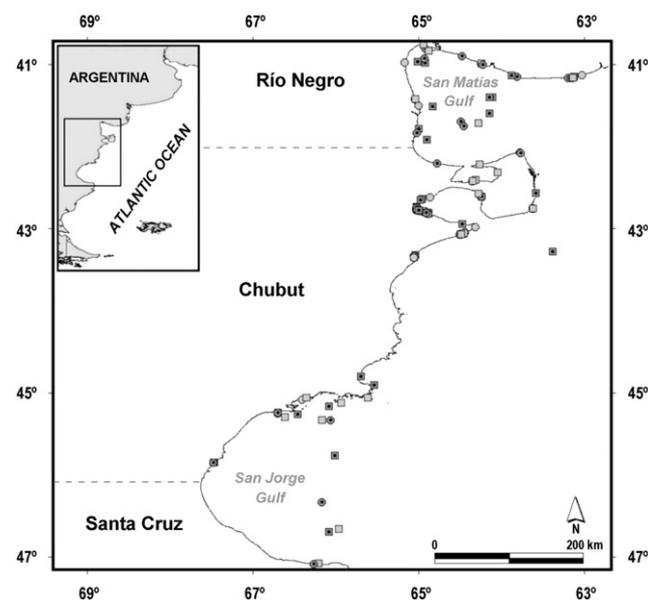
## Material and methods

### Collection of specimens

A total of 219 South American sea lions were collected along the coast of Patagonia during the period 1989–2008. Of these, 117 were males and 102 females. Most animals were found dead on the coast and some of them had been incidentally caught in commercial trawl fisheries. Standard body length (SL) was measured to the nearest cm using standard methods (Committee on Marine Mammals 1967). When they were present, canine teeth were taken for age estimation; otherwise the first post-canine tooth was used. From those animals that were recently dead reproductive tracts were dissected out, including intact pairs of testes from males ( $n=49$ , Fig. 1), and ovaries, and in some cases the uterus, from the females ( $n=61$ , Fig. 1). These samples were preserved in 10% formaldehyde or Bouin solutions. This variation in handling of the material was due to the fact that the sampling was performed by different people working under various conditions. For the same reasons complete sets of data were not available for all of the sea lions collected.

### Teeth preparation and age estimation

Individual ages were estimated from counts of incremental growth layers in the dentine of tooth sections, and few samples which the dentine was too pale the reading was made in the cementum growth



**Fig. 1.** Map of Patagonia showing the stranding and incidentally caught locations of South American sea lions (dots = females; squares = males; filled symbols = samples of reproductive tracts).

layers. Two different preparation methods were used: acid etching and thin ground sections. In the former the canine tooth was sectioned longitudinally through the centre of the pulp cavity using a handsaw, polished with sandpaper (400–1000 grit), then decalcified (in 5% formic acid) for 6–26 hs depending on the tooth size, washed overnight in running water, and finally dehydrated with acetone. The latter technique was used for female canine or post-canine teeth (i.e., when there were no canine teeth); the tooth was polished longitudinally up to the centre of the pulp cavity with sandpaper (400–1000 grit) obtaining a translucent section of 0.4 mm approximately.

The tooth sections were examined under a stereomicroscope with transmitted light in order to count growth layer groups (GLGs). It is known for this species that 1 GLG represents a one-year period (Laws 1962; Crespo 1988; Rosas et al. 1993). Each tooth section was read a minimum of two times by three independent readers. If two of the three readings were the same, that age was assigned to the tooth. If all the estimates differed but by no more than one year, the mean was used; if all the estimates differed, by more than one year, sections were re-examined or re-prepared. For reduced bias in body growth curves calculations, age was converted to the nearest month or 0.1 year (McLaren and Smith 1985), taking into account the difference between the median birth date for any colony (i.e., all specimens were assumed to have born the 15th of January) and the death date.

## Reproductive biology analyses and definitions

When possible, entire reproductive tracts were removed and examined. Ovaries were measured, weighed and measurements were averaged. They were then hand-sectioned parallel to the attachment of the ovarian ligament at 2 mm intervals, and examined macroscopically to record the number of corpora in each ovary. Four types of corpora were identified: (1) fresh corpora lutea (CL) from a recent ovulation of the new cycle, (2) regressing corpora lutea resulting from pregnancy in the preceding cycle (i.e., new corpora albicantia), (3) corpora albicantia (CA) from earlier pregnancies or ovulations, and (4) graafian follicles (F). Histological preparations were made by conventional method and stained with haematoxylin and eosin and with trichromic of Masson to differentiate between CLs and CAs from each animal. When possible, the diameters of the uterine horns were measured and averaged, and then each uterus was opened and examined for the presence of an embryo or foetus and placental attachment sites as signs of pregnancy.

Age at sexual maturation was defined as the age at which it has first ovulated (DeMaster 1978). Evidence of

ovulation was taken as the presence of at least one CL or CA in the ovaries. This definition assumes that CAs remain visible in the ovaries at least until the next ovulation (Perrin and Donovan 1984). The average age at sexual maturation (*ASM*) for the female population was defined as the age at which 50% of the females are mature ( $A_{p50}$ , DeMaster 1984), estimated by fitting a GLM with binomial error structure (with logit link function) to the proportion of mature females in each age class  $p_x$ :

$$p_x = \frac{CL_x + CA_{x+1}}{n_x + n_{x+1}}$$

where  $CL_x$  is the number of females of the age class  $x$  with one corpora lutea,  $CA_{x+1}$  is the number of females of the age class  $x + 1$  with one recent corpora albicantia,  $n_x$  is the number of females of the age class  $x$ , and  $n_{x+1}$  is the number of females of the age class  $x + 1$  (Smith 1973). A bootstrap sampling procedure was performed by which females of all age classes were resampled with replacement ( $N = 52$ ). Then for each resampling event a new  $p_x$  series was obtained, and  $A_{p50}$  was estimated again. This procedure was repeated 5000 times, calculating a mean value for *ASM* and its bootstrap generated distribution.

For males each pair of testis was measured, weighed and measurements were averaged. A sample was cut from the centre of the testis and epididymis from each male for histological examination. Males were defined as immature or mature according to criteria adapted from Hohn et al. (1985):

Immature: Seminiferous tubules are narrow and embedded in an abundant interstitial tissue. There are only spermatogonias in the tubular wall. The lumen of the epididymis is small and completely empty.

Mature: Almost no interstitial tissue is present. Seminiferous tubules are big, with many layers of cells with spermatocytes, spermatids and spermatozoa. The epithelium of the epididymis is growth and ciliate and the lumen may be full of spermatozoa.

These definitions were used to define physiological sexual maturation. Additionally the increment in size of the testes was used to estimate age when a male became social-sexually mature (i.e., begins mating activities in a breeding colony) (Andersen et al. 1999).

## Growth curves

Body growth in pinnipeds usually has a sigmoidal pattern (York 1983; Hammill et al. 1995; Hårding and Härkönen 1995; Frie et al. 2003). Therefore we described the South American sea lion growth using the most commonly used body growth models in pinnipeds defined by the following equations:

$$L(t) = L_{\infty}(1 - e^{-k(t-t_0)}) \quad \text{von Bertalanffy} \quad [A]$$

$$L(t) = L_{\infty}(e^{-e^{-k(t-t_0)}}) \text{ Gompertz} \quad [\text{B}]$$

where  $L(t)$  is the length (cm) at age  $t$ ,  $t$  is a unit of time in years (estimated from growth layer groups present in each tooth),  $t_0$  is the hypothetical age at which length is zero,  $L_{\infty}$  is the asymptotic length (e.g., the average length the species reach if it grows indefinitely),  $k$  is the growth-rate and  $e$  is the natural logarithm base. These parameters were obtained by Maximum Likelihood estimates in R v.2.5.1 (R Development Core Team 2008). Evidence in favour of competing models was evaluated on the basis of lowest Corrected Akaike Information Criterion ( $AICc$ ), smallest Delta  $AICc$  ( $\Delta AICc$ ), and highest  $AICc$  weights ( $w$ ) (Burnham and Anderson 2004). All models having a  $AICc \leq 2$  were considered as having substantial support. Growth curves were calculated for males and females, and parameters for all models are presented to assist comparison between populations and species (Hammill et al. 1995). The exponential phase of the growth curve is commonly used to define the sexual maturation phase of mammals (Pitcher and Calkins 1981; Laws and Sinha 1993). Laws (1956) found that South American sea lion females reached  $ASM$  at 80.8% of their final size, but the data used were aged according physical characteristics (i.e., relative body size and colour; Hamilton 1939). So using the adjustment of body growth curves to age, we test Laws' (1956) statement, and estimated the relative lengths of males and females at sexual maturity.

## Results

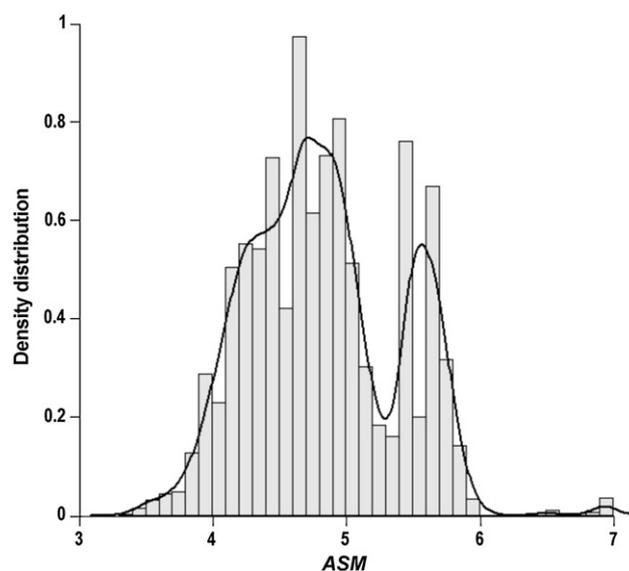
### Reproductive biology

Of the 219 South American sea lions collected only 110 could be used for the reproductive biology analyses. Of the 61 females examined, 17 were classified immature and 44 mature; seven of these females were pregnant. There were differences between ovaries and uterine horns from mature and immature females (Table 1). The mature animals have heavier (Mann-Whitney test,  $z = -5.90$ ,  $P < 0.001$ ) and larger ovaries than immature females (Mann-Whitney test,  $z = -5.83$ ,  $P < 0.001$ ). Their uterine horn diameters were also larger for mature females (Mann-Whitney test,  $z = -4.39$ ,  $P < 0.001$ ). Ovulation occurred in alternate ovaries each year, as evidenced by the CL and the most recent CA occurring in different ovaries.

The  $ASM$  was estimated as  $4.8 \pm 0.5$  years ( $\bar{x} \pm SD$ ), and the bootstrap distribution is drawn in Fig. 2. The earliest ovulation observed occurred during the 4th year, but if the ovulation occurs so early in the season as to allow impregnation, first birth may occur at 4 years old.

**Table 1.** Measurements of reproductive organs for females Southern sea lions by sexual maturation.

|                                   | Mean $\pm$ SE    | Range      | <i>n</i> |
|-----------------------------------|------------------|------------|----------|
| <b>Ovaries size (mm)</b>          |                  |            |          |
| Immature                          | 17.04 $\pm$ 0.58 | 13-21.15   | 17       |
| Mature                            | 36.85 $\pm$ 1.13 | 23.87-54.5 | 36       |
| <b>Ovaries weight (g)</b>         |                  |            |          |
| Immature                          | 1.30 $\pm$ 0.18  | 0.3-3.25   | 17       |
| Mature                            | 16.31 $\pm$ 1.2  | 5.7-38     | 39       |
| <b>Uterine horn diameter (mm)</b> |                  |            |          |
| Immature                          | 7.53 $\pm$ 0.57  | 5.5-11.09  | 11       |
| Mature                            | 32.03 $\pm$ 3.22 | 15.35-62.5 | 17       |



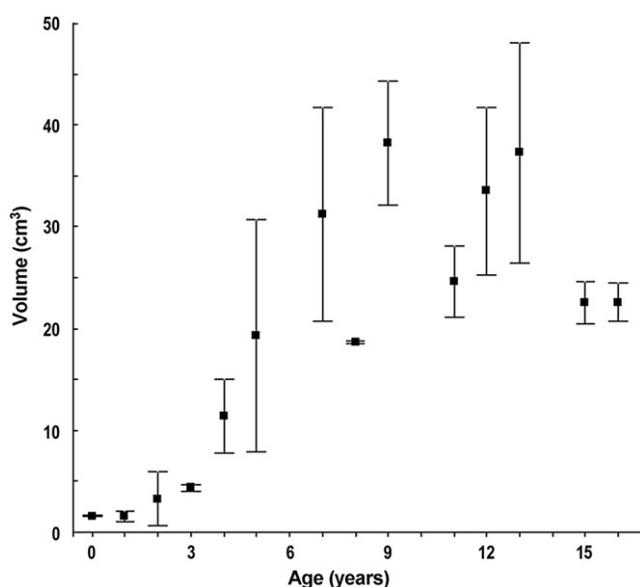
**Fig. 2.** Density distribution of the average age at sexual maturity ( $ASM$ ) for female South American sea lions.

All females 5 years and older were sexually mature. The oldest females (i.e., 18- to 21-year-old) had been reproductive ( $n = 5$ ). They had at least one CL or CA in the ovaries, and two of them had signs of pregnancy (i.e., enlarge uterine horns or mammary glands with milk present).

Of the 49 male specimens histologically examined, 24 were classified immature, and 25 mature. There were differences between testis from mature and immature males (Table 2). Sexually mature animals have heavier (Mann-Whitney test,  $z = -5.87$ ,  $P < 0.001$ ) and greater testis than immature males (Mann-Whitney test,  $z = -5.94$ ,  $P < 0.001$ ). The volume of testis of mature males was bigger than immature ones (Mann-Whitney test,  $z = -5.26$ ,  $P < 0.001$ ). The youngest animal classified as mature was 4 years old, and all males 6 years old or older were physiologically mature (i.e., they

**Table 2.** Measurements of testis for males Southern sea lions by sexual maturation.

|                                  | Mean $\pm$ SE    | Range       | <i>n</i> |
|----------------------------------|------------------|-------------|----------|
| Testis weight (g)                |                  |             |          |
| Immature                         | 4.91 $\pm$ 0.94  | 0.95–19.75  | 24       |
| Mature                           | 34.72 $\pm$ 2.76 | 15.25–60.25 | 24       |
| Testis size (mm)                 |                  |             |          |
| Immature                         | 34.29 $\pm$ 2.23 | 18.5–57.13  | 24       |
| Mature                           | 70.94 $\pm$ 2.21 | 52.9–87.5   | 25       |
| Testis volume (cm <sup>3</sup> ) |                  |             |          |
| Immature                         | 4.29 $\pm$ 0.83  | 0.75–13.9   | 22       |
| Mature                           | 29.63 $\pm$ 2.46 | 12.03–43.74 | 17       |

**Fig. 3.** Relationship between testis volume (mean  $\pm$ SD) and increasing age in South American sea lions.

had spermatozoa in the lumen of seminiferous tubules and epididymis). Testes volume showed a marked increase in size from 3 to 9 years old of age, and after 9 years old the growth of the testes did not showed a pronounced increase (Fig. 3). Using these indirect methods of determining age at sexual maturity we could indicate that all males became social-sexually mature at the age of 9 years.

### Growth curves

The age of animals used in the growth analysis ranged from 0 to 21 years for females and from 0 to 17 years for males. The sample was characterized by large numbers of young animals and a few older ones (Fig. 4). The sample for females and males up to 2 years old was

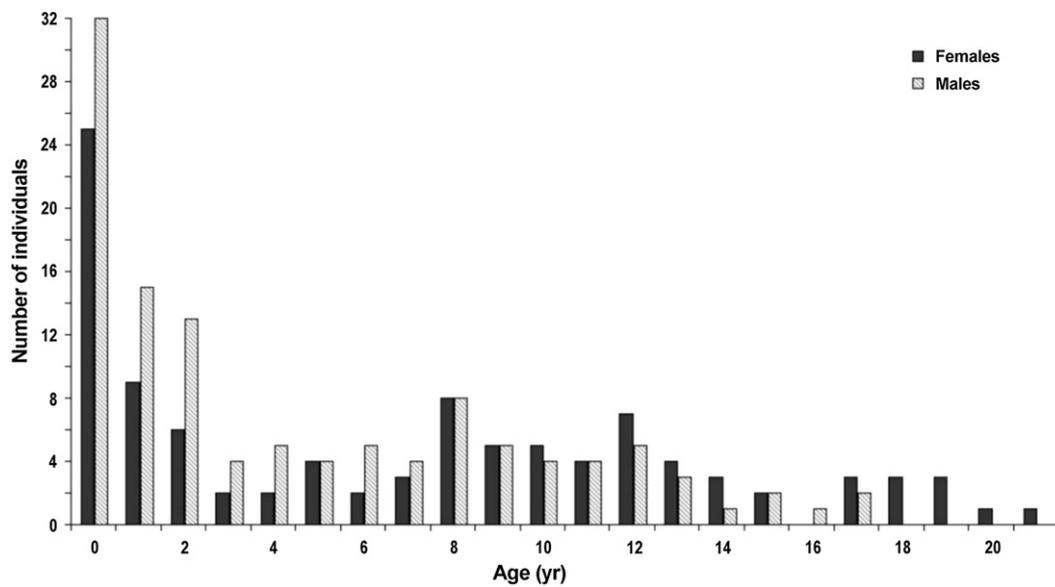
larger (range: 6–25 and 13–32, respectively) than the sample for animals older than 2 years (range: 1–9 in both sexes) (Fig. 4). Ages were estimated with an error of  $-0.05 \pm 0.86$  years ( $\bar{x} \pm SD$ ), and there were no differences among readers (Kruskal-Wallis test,  $H_{2, 400} = 0.606$ ;  $P = 0.738$ ).

The Gompertz curve fit male sea lions slightly better than the von Bertalanffy, and there was negligible difference in the  $AIC_c$  values for females (Table 3). We then used Gompertz curves to describe the growth pattern for males and females. The maximum recorded SL for males and females was 264 cm and 200 cm, respectively. The growth rate of males is relatively constant up to about 5 years of age, then decrease to an asymptote. Thus, males sustained a higher rate of growth in length for a longer period of time than females did (Fig. 5). Considering that male sea lion mature socially during the 9th year of life, they would reach maturity at 212 cm, about 86% of their asymptotic body length (Fig. 5).

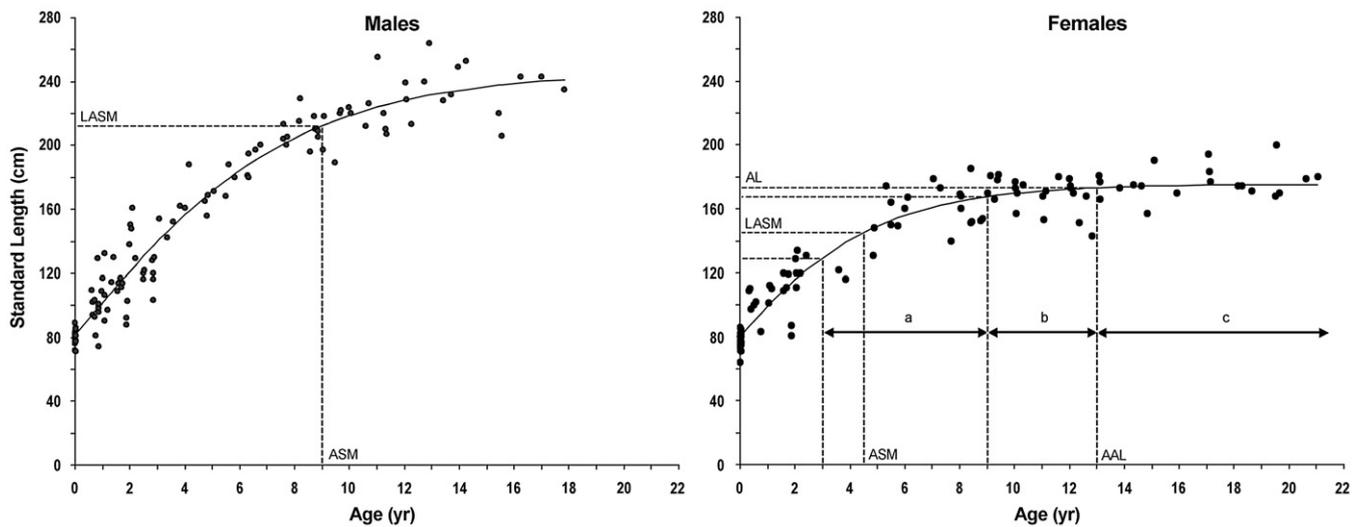
In agreement with Dabin et al. (2004) who described the female growth curve into 3 phases (a: the sexual maturation phase, defined by the exponential growth phase of the Gompertz curve, b: the asymptotic length attainment phase, where the growth rate start to decrease with age, and c: the physical maturation phase, which starts when the body growth reach the asymptotic length) we found that the female growth curve of South American sea lion showed the same three phases at different ages: a) phase of sexual maturation occurs in the 3- to 9-year-old age group, b) the phase of asymptotic length attainment take place between 9 to 13 years, and c) the physical maturation phase after 13 years of age (Fig. 5). Females reached maturity during the 4th year of life, corresponding to a mean SL of 140 cm, about 80% of their asymptotic length (Fig. 5). At SLs above 80% of the asymptotic length, all females were found to have been sexually mature.

### Discussion

We found that females had longer life spans than males, which agree with the majority of pinniped species. Male otariid tend to have life spans shorter than those of females, perhaps because territorial males generally live “hard and fast” in comparison with females (Riedman 1990). Maximum ages in our sample were 21 years for females and 17 years for males, which are older than *Otaria* from Brazil (Table 4). Other estimates for South American sea lions suggest maximum ages of 19 year for males (Crespo 1988) and 21 year for females, comparable with estimates from other otariid species (Boyd and Roberts 1993; Wickens 1993; Lima and Páez 1997).



**Fig. 4.** Age–frequency distribution of female ( $n = 102$ ) and male ( $n = 117$ ) South American sea lions that were used for development of growth models in this study.



**Fig. 5.** Gompertz growth function fitted to standard length data for males and females South American sea lions (see Table 3 for parameter values). ASM, age at sexual maturity; LASM, length at sexual maturation; AL, asymptotic length; AAL, age at asymptotic length; a, sexual maturation phase; b, asymptotic length attainment; c, physical maturation phase.

The maximum recorded length of male and female South American sea lion from Patagonia were similar to those from Falkland (Malvinas) Islands and Uruguay (Table 4). Patagonian sea lions, both males and females, had smaller asymptotic and maximum lengths than sea lions from Southern Brazil (Rosas et al. 1993) (Table 3 and 4). Such differences are not likely due to measurement discrepancies among fieldworkers, because the measurement and age estimation methods were the same. The main differences are due to the

greater length of young age classes (2–5 years old in males and females) from Southern Brazil (Rosas et al. 1993). It is possible this variation is due to sample bias; our sample has fewer specimens between 2 and 7 years old and more individuals of older age classes than the Brazilian sample. But also the smaller body length from specimens from Patagonia could be due to intraspecific variability with latitude or differences between colony sites related to genotypic traits (Túnez et al. 2007), or a combination of these factors.

**Table 3.** Parameters of growth functions (see Eqs. [A] and [B] in the text) fit to data on body length-at-age for South American sea lions.

| Growth curve    | $L_{\infty}$ | $k$   | $t_0$ | $n$ | K | $\Delta AICc$ | $w$   |
|-----------------|--------------|-------|-------|-----|---|---------------|-------|
| Females         |              |       |       |     |   |               |       |
| von Bertalanffy | 177.33       | 0.244 | -2.42 | 102 | 3 | 0.0           | 0.624 |
| Gompertz        | 175.41       | 0.313 | -0.78 | 102 | 3 | 1.0           | 0.376 |
| Males           |              |       |       |     |   |               |       |
| von Bertalanffy | 260.64       | 0.142 | -2.54 | 117 | 3 | 3.7           | 0.136 |
| Gompertz        | 246.23       | 0.223 | 0.451 | 117 | 3 | 0.0           | 0.864 |

$n$  = number of individuals included in the analysis; K = number of parameters of the model;  $\Delta AICc$  = delta Corrected Akaike Information Criterion;  $w$  =  $AICc$  weights.

**Table 4.** Maximum recorded length and age of male and female *O. flavescens* from different areas.

| Area                      | Males    | Females  | References                  |
|---------------------------|----------|----------|-----------------------------|
| Southern Brazil           | 266 cm   | 16 year  | Rosas et al. (1993)         |
| Uruguay                   | 245 cm   | 200 cm   | Vaz-Ferreira (1982)         |
| Patagonia                 | 264 cm   | 19 year* | Crespo 1988; and this study |
| Falkland/Malvinas Islands | 256.4 cm | 195.6 cm | Hamilton (1934, 1939)       |

In pinnipeds, females reach sexual maturity more quickly than males. These differences especially make sense in view of the more pronounced sexual dimorphism and highly polygynous breeding system characterizing all the otariids (Riedman 1990; Cassini 1999). Based on gonad analysis our results suggest that sexual maturity in males is attained between 4 and 7 year old, which is consistent with previous studies (Vaz-Ferreira 1982) and with several other otariid species, such as the Steller sea lion, *Eumetopias jubatus* (Pitcher and Calkins 1981) and Australian sea lion, *Neophoca cinerea* (Reijnders et al. 1993). In the case of males we distinguish physiological *ASM* and age at 1st reproduction (i.e., 1st mating). Although young males may be physiologically mature, reproductive maturity may be delayed until a male can physically secure a breeding territory (Campagna 1985), which in turn may depend on attainment of a certain size or fighting ability (Campagna and Le Boeuf 1988). Even though non-territorial males may occasionally mate with females on the periphery of territories (Campagna et al. 1988a, b), the age at 1st territory tenure is a valuable criterion for estimating *ASM* in males. As with other pinniped species (Wickens and York 1997; Winship et al. 2001), male South American sea lions reach significantly larger sizes than females, sustaining a higher rate of growth in length for a longer period of time (Fig. 5), and this maintenance of growth could be related to the phase of puberty. Although most males mature sexually before reaching 86% of asymptotic length, they usually are not socially mature and able to hold a territory until 9-11

years (Crespo 1988), which is consistent with the development of the testicles (Fig. 3) and corresponds to a mean body length of 212 cm.

We found that female *ASM* occurs during the 4th year of life, and age at first birth occurs between the 4th and 5th year, which agrees with the scarce published data available for this species (Vaz-Ferreira 1982). It is also a slightly lower *ASM* than the 5 years approximated through indirect estimation by matrix population models (Crespo 1988). This result constitute a starting point for long term studies that investigate the variations in South American sea lions *ASM* related to colony age or density. The ovaries of South American sea lion are similar in gross anatomy, and in development of CLs and CAs, to those of other pinniped species (Laws and Sinha 1993). It appears that CAs do not last longer than about 2 years in the ovaries, but 31% of the mature females presents more than one CA in the ovaries, which considering the assumption of Smith's method, could result in an over-estimate of the *ASM* obtained. So  $4.8 \pm 0.5$  years ( $\bar{x} \pm SD$ ) should be taken as a maximum *ASM* for *O. flavescens* females. When combining these findings with information from the female growth curve (Fig. 5), it coincides with the marked slowing of growth at 3-9 year which is associated with the attainment of sexual maturity. In addition, the length at *ASM* ( $L_{ASM} = 147.6$  cm) will be reached at 81% of the final length, which is consistent with the description by Laws (1956). Sexual maturation is followed by a physical maturation phase, which occurs with the asymptotic length ( $AL = 173.1$  cm)

reached here for individuals older than 13 years old. In spite of having at least one ovarian corpus (CL or CA), none of three females older than 19 years was pregnant. These observations could possibly indicate reduced fecundity in older age classes. Among pinnipeds, a decrease in fecundity has been observed in northern fur seals (York and Hartley 1981; Trites 1991), Antarctic fur seals (Lunn et al. 1994; Boyd et al. 1995), Subantarctic fur seals (Bester 1995; Dabin et al. 2004), New Zealand fur seals (Dickie and Dawson 2003) and monk seals (Harting et al. 2007). So, further studies must be performed to estimate pregnancy rates of South American sea lions to detect reproductive senescence or a decline in the reproductive activity.

Several factors may influence the analysis of life-history parameters, as *ASM* and body growth (McLaren and Smith 1985; Hammill et al. 1995). First, sampling bias is one of the potential factors that can mainly affect the sample of the age structure. Due to behavioral characteristics, juveniles are segregated from breeding areas, leading to the formation of different types of colonies depending on their social composition (Dans et al. 2004; Grandi et al. 2008). In addition foraging patterns vary with age-sex classes (Koen Alonso et al. 2000) and probably with reproductive condition. If pregnant females and younger animals have reduced swimming/diving ability, fishing trawlers are unlikely to catch all age classes equally (Crespo et al. 1994; Rosas et al. 1994). Pregnant females could be less likely to become caught in nets compared to immature or non-pregnant ones, but on the other hand they could be more likely to strand in rookeries due to problems in labor or aggressive harassment behaviors. To reduce this bias we included in our sample animals from all types of rookeries and by-catch animals from different fishing gears. Second, variability among cohorts may also influence growth curves. Thus we did not analyze growth by following individual cohorts through time but instead examined the cross-sectional relationship between length and age in samples collected over a period of 19 years. The resulting curves would reflect average environmental conditions faced by several cohorts within a population rather than specific conditions encountered by following a single cohort. Finally, the third factor that can affect the population estimates is the effects of errors in age determination that tend to lead to biased estimates of growth parameters (Leberg et al. 1989). The methodology used was widely proved for the species (Crespo 1988; Rosas et al. 1993) and the estimated error was negligible so it would not represent a significant bias in this case. Furthermore, the use of aged animal to 0.1 years and a wide range of ages in our sample will likely improve our parameters estimate (McLaren and Smith 1985).

Our findings support the idea that the 81% of the asymptotic length could be used as a good estimate of

*ASM* in females sea lions when there is a lack of reproductive tracts samples. The present information on *ASM* and growth of South American sea lion will make possible further investigations of reproductive processes and body condition that are essential for the assessment of population dynamics models and life history of any recovered population of pinnipeds throughout time.

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