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COMPARATIVE GROWTH ANALYSIS OF TWO POPULATIONS OF *PONTOPORIA BLAINVILLEI* ON THE BRAZILIAN COAST

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ABSTRACT

The von Bertalanffy growth model was applied to franciscana dolphins (*Pontoporia blainvillei*) incidentally caught in fishing nets on the São Paulo/Paraná coasts (25°00′–25°58′S), and compared with the growth of franciscanas incidentally caught on the Rio Grande do Sul coast (29°–33°S). In both locations, a difference was noted between the growth of males and females, confirming the sexual dimorphism of the body proportions of this dolphin. The growth curves of the dolphins from São Paulo/Paraná were significantly different ($P < 0.01$) from those obtained from Rio Grande do Sul, with significantly smaller animals in the former area. On the São Paulo/Paraná coast, the stabilization of the growth curves happened at a total length of 113 and 129 cm for males ($n = 23$) and females ($n = 18$), respectively. In Rio Grande do Sul, they stabilized at 130 cm for the males ($n = 59$) and at 146 cm ($n = 48$) for the females. These results corroborate the morphometric differences previously mentioned in the literature, which resulted in the identification of a smaller northern form and a larger southern form of *P. blainvillei*. The data here presented can be used for future comparisons of changes in growth parameters of these two franciscana stocks and help to develop proper conservation programs for the species.

Key words: Franciscana, *Pontoporia blainvillei*, growth, modeling, South America.

Growth is a result of biochemical, physiological, and genetic processes. The potential for growth in each individual can be altered due to many different aspects including, but not limited to, food availability, diseases, and stress. Therefore, by comparing the growth patterns of populations submitted to incidental captures with unexploited populations in similar environmental conditions, changes in life strategies can be identified and an idea can be obtained about the impact of captures on it. The franciscana dolphin, *Pontoporia blainvillei*, is a species threatened in several parts of its distribution due to incidental captures (Praderi *et al*. 1989, Pinedo 1994, Siciliano 1994, Pinedo and Barreto 1997, Bertozzi and Zerbini 2002, Rosas *et al*. 2002, Secchi *et al.* 2002), and has recently been considered "vulnerable" by IUCN (Secchi and Wang 2003), making studies that identify populations indispensable. The study of somatic growth is also very important in order to understand the biology of a species, as well as being a tool to identify stocks. At least two different *P. blainvillei* populations have been detected based on morphology, with smaller individuals distributed between 22° and 27°S (northern form), and bigger ones distributed between 32° and 38°S (southern form) (Pinedo 1991). This has been corroborated by a genetic study (Secchi *et al*. 1998) and by geometric morphometric analysis (Higa *et al.* 2002). Further studies have indicated that probably more than two populations exist, which led to the proposal of four management stocks (Sechi *et al.* 2003). According to Rosas (2000), the morphological and growth pattern differences between the northern and southern forms are not a mere clinal variation of the species. This has been corroborated by Ramos *et al*. (2002), who mentioned that different body sizes and growth patterns may occur within population stocks independent of latitudinal distribution, and that studies based on cranial morphology have shown that there are more than two populational stocks of *P. blainvillei*.

By using mathematical models to study growth, growth metrics can be standardized and thus growth patterns of different populations can be compared statistically. Several growth models have been developed over the years, but each model has its peculiarities and sometimes it is difficult to know which one should be used. Many times researchers choose a growth model that has been previously used for the species, without testing whether the model is the most adequate for the growth characteristics of that species. Considering the computational power currently available, it is easy to test different growth models, and therefore, the choice of which model to use should be determined by the best fit of the data. Also, the development of generic models helps to choose the model that is best adapted to the length and age data of the species being studied.

The present study compares the growth of *P. blainvillei* incidentally caught in fishing nets or stranded on the Rio Grande do Sul coast, with franciscanas incidentally caught on the Paraná and southern São Paulo coasts.

Materials and Methods

The data used in this study were obtained from incidentally caught or stranded animals on the southern coast of São Paulo and Paraná (SP/PR area) and on the coast of Rio Grande do Sul (RS area) (Fig. 1). In Rio Grande do Sul (29°20′–33°45′S), individuals were collected from 1979 to 1986 and in Paraná and São Paulo (25°00′–25°58′S) they were recorded between 1997 and 1999. For the RS area, dolphins were collected during systematic beach surveys, where all stranded animals were collected. While most of them exhibited signs of fishery interactions (see Pinedo and Polacheck 1999), the exact amount that had died due to incidental capture is not known. According to Pinedo (1994), the gill nets commonly used by artisanal fisheries are the main cause of incidental catches of franciscana in RS. For the SP/PR area, all dolphins here analyzed were incidentally caught in gillnets. The description of the fisheries and the number of dolphins caught in that area were presented by Rosas *et al*. (2002).

The total body length was measured linearly, from the central notch of the tail up to the tip of the rostrum. The age was estimated by counting growth layer groups

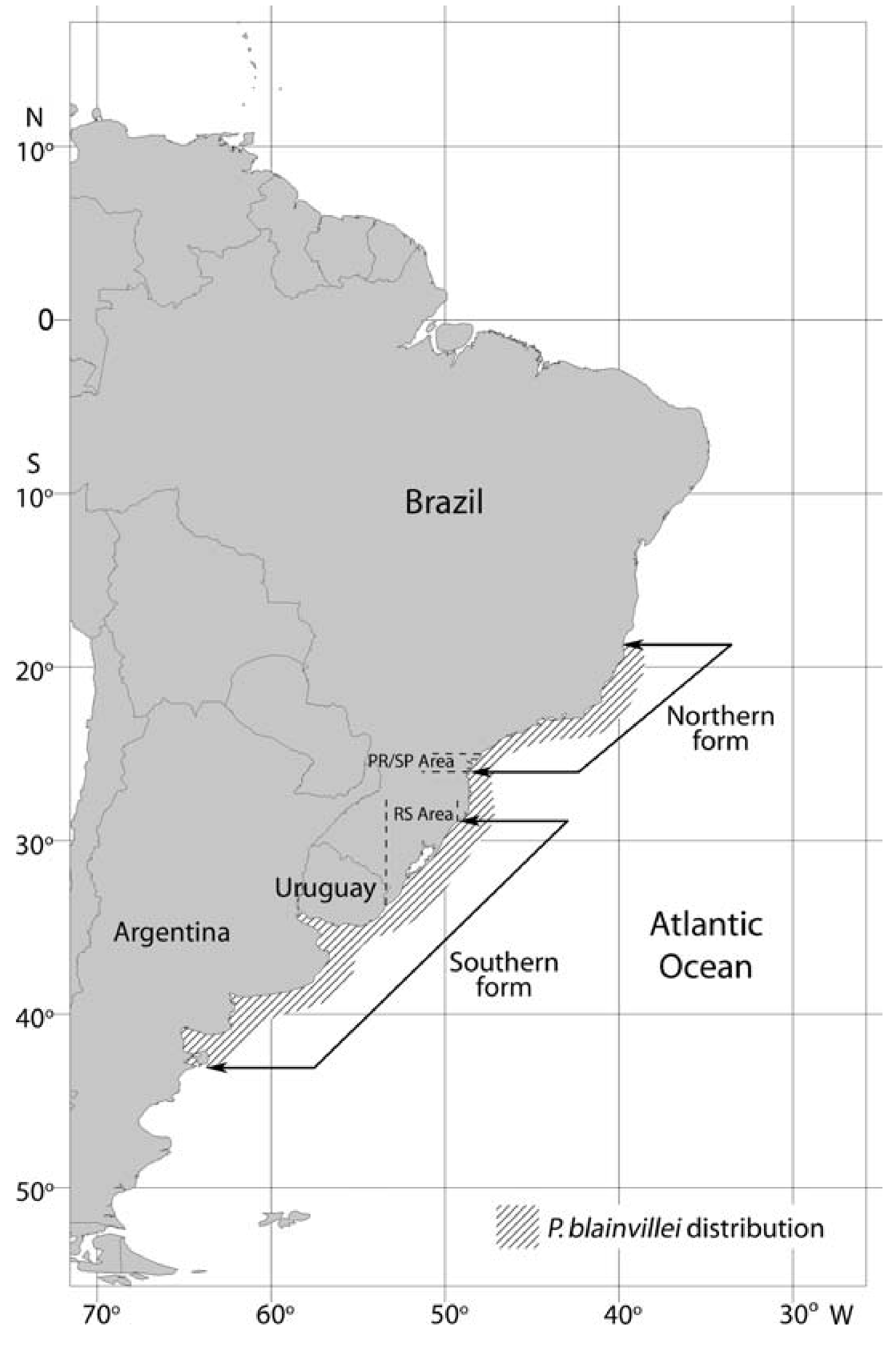

Figure 1. Distribution of *Pontoporia blainvillei*, indicating the northern and southern forms. The area of incidentally caught dolphins from São Paulo/Paraná States is indicated by "PR/SP Area," and the area of incidentally caught dolphins from Rio Grande do Sul State is indicated by "RS Area." Adapted from Pinedo (1991).

Table 1. Special cases of Schnute's general growth model (Schnute 1981). For a description of the models and their origins, see Ricker (1979).

Parameters	Specific growth model
$a > 0, b > 0$	Generalized von Bertalanffy
$a > 0, b = 1$	Specialized von Bertalanffy /Pütter no. 1
$a > 0, b = 1/3$	Pütter no. 2
$a > 0, b = 0$	Gompertz
$a > 0, b < 0$	Richards
$a > 0, b = -1$	Logistics
$a = 0, b = 1$	Linear
$a = 0, b = 1/2$	Quadratic
$a = 0, b = 0$	*n*-Potential
$a < 0, b = 1$	Exponential

(GLGs), using the method described by Hohn *et al.* (1989) and Pinedo and Hohn (2000). Fetuses were not included in the analyses and in order to better adjust the growth curve, the ages of individuals less than 1 yr (<1 GLG) were fractionated. This resulted in a sample of 107 individuals from RS (59 males, 48 females) and 41 from Paraná and southern São Paulo (23 males, 18 females).

Knowing that *P. blainvillei* has sexual dimorphism in terms of body sizes (Kasuya and Brownell 1979, Pinedo 1995), the growth equations of the sexes were calculated separately.

The use of the Schnute model (1981) allows an impartial choice of the growth model, based uniquely on the data available. This is a general model that includes most of the other models as special cases (Table 1). The generic growth model proposed by Schnute is described as

$$Y(t) = \left[\gamma_1^b + \left(\gamma_2^b - \gamma_1^b\right) \frac{1 - e^{-a(t-\tau_1)}}{1 - e^{-a(\tau_2-\tau_1)}}\right]^{1/b}$$

where $Y(t)$ represents length at age t. Variables τ_1 and τ_2 are ages of young and old specimens, respectively, and γ_1 and γ_2 are sizes at these ages. The τ_1 and τ_2 values are defined based on the sample, and the sizes, together with a and b, are the parameters which will be estimated. Growth model adjustment to the data was made using the non-linear iterative Quasi-Newton method, minimizing the sum of squared residuals.

One of the most widely used models, specially in fisheries biology, is the von Bertalanffy growth function. It is also one of the most studied models due to its mathematical characteristics and the biological meaning of its parameters. The generalized von Bertalanffy's model, proposed by Pauly (1981, in Pauly 1984), can be described by

$$M_t = M_\infty \times \left[1 - e^{-kD(t-t_0)}\right]^{1/D}$$

where M_t corresponds to a measurement at age t, M_∞ is the asymptotic value of this measurement, e is the base of the natural logarithm, t_0 is a parameter for a better fit of the curve and represents the theoretical age where the animal has zero length, and

k is a parameter of the curve that determinates how fast the animal reaches M_∞. The parameter D is related to metabolic rates and the relationship between body weight and the organism length. When $D = 1$, we have the specialized von Bertalanffy's equation:

$$M_t = M_\infty \times \left[1 - e^{-k(t-t_0)}\right]$$

which is more commonly used to describe the growth of many organisms, including cetaceans (Borobia 1989, Cockcroft and Ross 1990, Rosas *et al*. 2003).

After defining which growth model was most appropriate, the growth curves obtained from RS and SP/PR were compared to test the hypothesis whether each of its parameters differed or not, by using the maximum likelihood method (Cerrato 1990).

Results

Most of the time the Schnute model applied to the data on age and total length of *P. blainvillei*, revealed an $a > 0$ and a $b > 0$ (Table 2). The b-value of the RS females was negative, which could indicate that the Richards model would be more suitable. On the other hand, we believe that this value could have been caused by a peculiar distribution of length data of the females between 0 and 3 yr from the RS area (Fig. 2). Therefore, taking into consideration the whole data set and results, it was decided to use the von Bertalanffy model for both sexes and locations.

Comparing the growth curves of males and females, statistically significant differences ($P < 0.05$) were noted between the asymptotic lengths of both areas (Fig. 2, Table 3). The growth of males in both populations stabilized at about 4 yr and that of the RS females at about 6 yr. The stabilization of the SP/PR females comes only at 10 yr, but this value is probably due to the lack of specimens with ages between 5 and 7 in our sample, which probably caused the model to flatten the curve. The growth curves of individuals from the coasts of SP/PR were significantly different ($P < 0.01$) from those obtained from the RS area, with significantly smaller individuals in the former area.

Table 2. Parameters of the Schnute model for male and female *Pontoporia blainvillei* incidentally caught on the coast of Rio Grande do Sul (RS) and southern São Paulo and Paraná (SP/PR). "SS" represents the sum of squares, "Var. Expl." represents the variance of the data explained by the model.

	Males		Females	
	RS	SP/PR	RS	SP/PR
τ_1	0	0	1	0
γ_1	701.47	655.95	1,138.65	754.94
τ_2	13	9	13	16
γ_2	1,309.44	1,172.29	1,451.93	1,311.02
a	0.61	0.10	9.68	0.10
b	4.78	9.88	−93.38	6.52
SS	311,592.82	23,809.66	449,478.26	14,622.84
Var.Expl.(%)	73.74	92.19	68.16	96.39
n	59	23	48	18

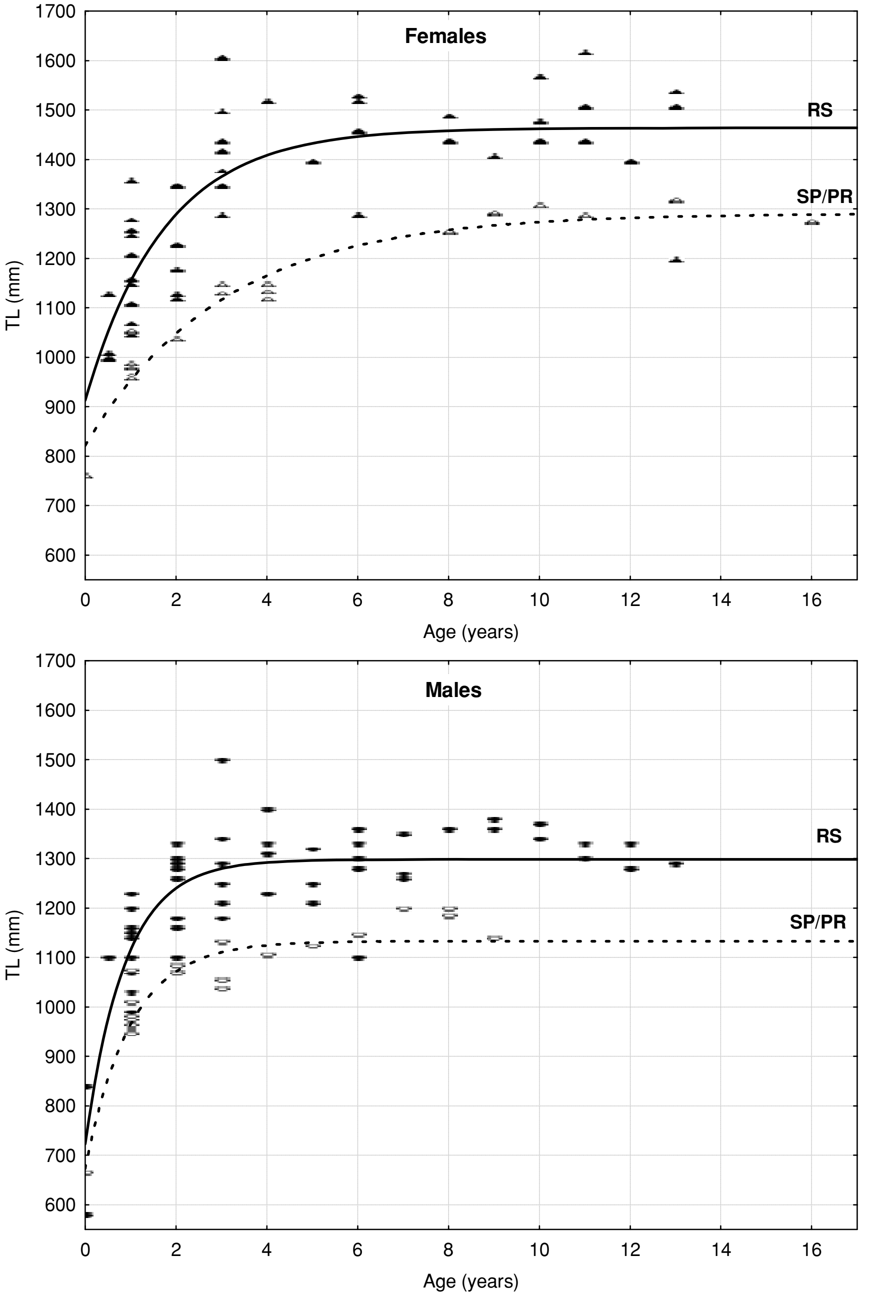

Figure 2. Growth curves of *Pontoporia blainvillei* incidentally caught in Rio Grande do Sul (RS) and southern São Paulo and Paraná (SP/PR) coasts. The lines represent the adjustment of the data to the von Bertalanffy model. Open symbols are specimens from the RS area and closed symbols are PR/SP specimens. Age is expressed in years. TL = total body length in mm.

Table 3. Parameters of the von Bertalanffy model for male and female *Pontoporia blainvillei* incidentally caught on the coast of Rio Grande do Sul (RS) and southern São Paulo and Paraná (SP/PR). "LT_∞" is the asymptotic total length, "SS" represents the sum of squares, "Var. Expl." represents the variance of the data explained by the model.

	Males		Females	
	RS	SP/PR	RS	SP/PR
LT_∞	129.8	113.3	146.3	129.1
k	1.14	1.00	0.57	0.33
t_0	–0.71	–0.90	–1.71	–3.07
SS	320,632.7	34,821.1	493,277.8	22,820.5
Var.Expl.(%)	72.98	88.58	65.05	94.37
n	59	23	48	18

Discussion

The growth differences between the two areas corroborate the results obtained by Pinedo (1991), where two geographical forms of *P. blainvillei* were observed, with larger individuals occurring in the south, and smaller ones in the north of the distribution of the species. Thus, the differentiation of the forms is not only due to the attributes of the adult specimens studied by Pinedo (1991), but also to their growth patterns presented here. It must be noted that the specimens used in this study were separated in to two groups considering the areas where they were collected, and not allocated specifically to either of the two previously identified geographical forms. Therefore, considering that the SP/PR area is close to what is considered the northern limit of the southern form, it is possible that the sample from this area may contain animals from the other stock.

When comparing the results of the present study between the two areas, the pattern appears to be the same as that predicted by Bergmann's Rule (Mayr 1970), with larger animals in colder regions. However, the results obtained by Ramos *et al.* (2000) for *P. blainvillei* from the north of Rio de Janeiro State (much farther north than the SP/PR coasts, approximately 21°S) indicated that the animals of that region reach asymptotic lengths which are greater (males = 117.1 cm; females = 144.7 cm) than those from southern SP/PR (males = 113.3 cm; females = 129.1 cm). The absence of clinal variation could be an indication that not only environmental factors are responsible for the variation in size, as previously mentioned by Ramos *et al.* (2002).

On the other hand, environmental aspects that do not change continuously with latitude could be responsible for the differences. Somatic growth has a strong dependence on the amount of food available to the organism. Other things being equal, animals with more food available should grow to larger sizes (Costa and Williams 1999). Higher availability of resources in Rio de Janeiro and RS, could have resulted in larger animals. Nevertheless, the results indicate considerable growth differences between franciscanas from RS and from Paraná/São Paulo areas, which is consistent with other biological data obtained for the species (Pinedo 1991, Sechi *et al.* 1998, Danilewicz *et al.* 2000, Higa *et al.* 2002, Ramos *et al.* 2002, Rosas and Monteiro-Filho 2002).

A factor that must also be considered is the temporal difference between the data collected from the two locations. The data from SP/PR were collected between 1997 and 1999, while those of RS were collected between 1979 and 1986, thereby having an interval of at least 11 yr between them. Changes in size and age structure of a population are expected when subjected to fishing effort, usually reducing mean body size and reproductive age (Jennings *et al.* 2001), and the franciscana dolphin is a species suffering from strong fisheries impacts (Praderi *et al.* 1989, Moreno *et al.* 1997, Secchi *et al.* 1997, Rosas *et al.* 2002, Secchi *et al.* 2002). However, comparing the reproductive parameters between the two areas, it can be observed that the females in RS attain sexual maturity between 3.3 and 3.7 yr (Danilewicz *et al.* 2000), while in São Paulo/Paraná sexual maturity occurs between 4 and 5 yr (Rosas and Monteiro-Filho 2002). Thus, the population with smaller individuals (SP/PR area) are maturing at older ages than the population with larger individuals (RS area), contradicting the general rule for overexploited populations. Therefore, either the effect of the incidental captures is acting only on the size and not on the age of sexual maturity, or the differences are inherent of the two geographical forms and not due to differential capture. It must be also considered that the small sample sizes used in the present study, especially from SP/PR ($n = 41$), limits the reliability of the growth parameter estimates. Large differences observed between the two areas in specific age classes with few animals, *e.g.*, length-at-birth, could have been due to sampling issues. According to Rosas and Monteiro-Filho (2002), birth length does not seem to be significantly different between the northern and southern forms, even though total body lengths are very distinct in the adult phase. Therefore, the results presented must be considered more in terms of patterns than for the specific values of the growth parameters.

According to Gearin *et al.* (1994), the impact of incidental catches on a population may affect recruitment rates and may also produce changes in growth rates of the individuals of that population (Calkins *et al.* 1998). Growth curve parameters provide a good index to measure temporal changes within a population, which has special importance in species submitted to incidental catches. Therefore, the data presented here can be used for future comparisons of eventual changes in growth parameters of these two franciscana stocks and help to develop proper conservation programs for the species. It is highly recommended to develop growth studies of franciscana dolphins from other populations within the two geographical forms (northern and southern forms) in order to develop a better management of stocks subjected to differential fishery impacts.

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