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Variation of age and total length in *Sotalia guianensis* (Van Bénéden, 1864) (Cetacea, Delphinidae), on the coast of Espírito Santo state, Brazil

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(With 4 figures)

Abstract

Variations of age and total length of *Sotalia guianensis* from the state of Espírito Santo, Brazil, were evaluated. Specimens were found stranded. Age and total length of 44 Guiana dolphins were assessed based on tooth analysis. Age varied between 0.5 year and 33 years (mean = 8.23 years). Most specimens were between zero and 6 years old (47%). Total length varied from 119 cm to 198 cm, with mean of 172.52 cm. Asymptotic length was reached at 185 cm and approximately 5-6 years of age. Mean total length and age were higher than in other regions of the distribution range of the species. Nevertheless, more studies have to be carried out to evaluate the morphological variations in *S. guianensis* populations in the study area and Brazil.

Keywords: Guiana dolphin, age, total length.

Variação etária e de comprimento total de *Sotalia guianensis* (Van Bénéden, 1864) (Cetacea, Delphinidae), no Litoral do Espírito Santo, Brasil

Resumo

Foram avaliadas variações de comprimento total e etárias de *Sotalia guianensis* provenientes do estado do Espírito Santo. Os espécimes foram encontrados encalhados. Idade e comprimento total de 44 *S. guianensis* foram avaliados com base na análise dentária. A idade variou entre 0,5 e 33 anos (média = 8,23 anos). A maioria dos exemplares tinha entre zero e seis anos de idade (47%). O comprimento total variou de 119 a 198 centímetros, com média de 172,52 centímetros. O comprimento assintótico foi atingido com 185 cm, aproximadamente entre 5-6 anos de idade. O comprimento total médio e a idade foram maiores que outras regiões de distribuição da espécie. No entanto, mais estudos devem ser realizados para avaliar as variações morfológicas em populações de *S. guianensis* na região e no Brasil.

Palavras-chave: golfinho das Guianas, idade, comprimento total.

1. Introduction

The Guiana dolphin (*Sotalia guianensis*, Van Bénéden, 1864) is found along the tropical and subtropical Atlantic coast of the South and Central Americas, from Honduras (Edwards and Schnell, 2001) to the state of Santa Catarina, Brazil (Simões-Lopes, 1988). Although it is one of the species that have been most studied in these regions, it is still considered insufficiently known by the International Union for Conservation of Nature (IUCN, 2003) and by the Brazilian environmental authorities (IBAMA, 2001).

Variations in growth pattern may be associated with seasonal changes, environmental factors, competition strategies, and patterns of reproduction investment (Amano and Miyazaki, 1992). Intraspecific morphological changes represent an important source of information in the identification of the variability of geographical and non-geographical elements. Currently, several types of data are used to identify populations. Studies about phenotypical characters (osteology, morphology, and pigmentation patterns) based on multivariate techniques have been consistently carried out to identify populations in several taxonomic groups (Wang et al., 1999).

Age estimates of cetaceans stand is a good tool to characterize populations and to understand the biology of individuals (Pinedo and Hohn, 2000; Butti et al., 2007; Azevedo et al., 2015; Carvalho et al., 2015). In this sense,

the ability to estimate the age of small cetaceans is extremely important in natural history studies (Hohn et al., 1989).

The present study determined age and morphology variations in the Guiana dolphin in the state of Espírito Santo, Brazil.

2. Material and Methods

In total, 44 specimens of *S. guianensis* accidentally captured in fisheries or stranded in the state of Espírito Santo, Brazil, were used. Detailed information on specimens recovered and used in this study are provided in Table 1. Individuals were found between Conceição da Barra (18°30'S), and Presidente Kennedy (21°05'S), farther south. Initially, total length (TL) and sex of animals were established. Next, teeth were extracted to estimate age. The teeth whose roots were straight and that exhibited the lowest degree of wear of crown were chosen, independently of their position in the mandibles. The method described by Hohn et al. (1989) was adopted. At first, teeth were cut to 3-mm to 5-mm-thick sections parallel to the longest bucco-lingual axis using a low-speed metal saw equipped with diamond blades. Sides of sections were also removed to improve the action of the decalcification agent and facilitate the subsequent sectioning of tooth specimens using a microtome-cryostat. Tooth sections were soaked

Table 1. *Sotalia guianensis* data used in this study. Information includes specimen identification, collection date, sex (male: M, female: F, UN: unknown sex), total length (cm), locality, city, tissues samples stored and responsible staff. All tissues samples were stored at the ORCA institute's head office.

Specimen	Collection date	Sex	Total length	Locality	City	Tissues samples stored	Responsible staff
SOT.05	18/03/1996	F	189	Itaparica	Vila Velha	Skeleton, teeth	L. Barbosa
SOT.19	09/03/2003	M	189	Jacaraípe	Serra	Skeleton, teeth	L. Barbosa
SOT.23	06/10/2003	M	172	Santa Cruz	Aracruz	Skeleton, teeth	L. Barbosa
SOT.30	04/04/2004	M	196	Siribeira	Guarapari	Skeleton, teeth	L. Barbosa
SOT.31	04/05/2004	UN	183	Meaípe	Guarapari	Skeleton, teeth	L. Barbosa
SOT.37	12/09/2004	UN	189	Formosa	Aracruz	Skeleton, teeth	L. Barbosa
SOT.42	01/09/2004	F	200	Ponta da Fruta	Vila Velha	Skeleton, teeth	L. Barbosa
SOT.44	19/11/2004	UN	187	Santa Cruz	Aracruz	Skeleton, teeth	L. Barbosa
SOT.45	06/04/2005	M	166	Regência	Linhares	Skeleton, teeth, lung, bone marrow, muscle, liver, brain	L. Barbosa
SOT.46	06/04/2005	M	173	Regência	Linhares	Skeleton, teeth, liver, lung, muscle	L. Barbosa
SOT.48	27/06/2005	F	162	Ilha do Boi	Vitória	Skeleton, teeth, liver, bone marrow, lung	L. Barbosa
SOT.52	10/01/2006	M	169	Regência	Linhares	Skeleton, teeth, bone marrow, muscle	L. Barbosa
SOT.53	16/01/2006	M	169	Regência	Linhares	Skeleton, teeth, muscle, liver, bone marrow	L. Barbosa
SOT.56	01/03/2006	M	158	Regência	Linhares	Skeleton, teeth, muscle, liver, bone marrow	L. Barbosa
SOT.57	14/03/2006	F	196	Setiba	Guarapari	Skeleton, teeth, muscle	L. Barbosa
SOT.58	17/03/2006	M	190	Ilha do Frade	Vitória	Skeleton, teeth, muscle, liver	L. Barbosa
SOT.62	02/01/2007	F	195	Costa	Vila Velha	Skeleton, teeth, muscle, lung, intestine proximal, distal bowel	L. Barbosa
SOT.64	17/01/2007	M	198	Mãe-Bá	Anchieta	Skeleton, teeth, lung, intestine proximal, distal bowel	L. Barbosa
SOT.66	22/01/2007	M	185	Barrinha	Vila Velha	Skeleton, teeth, muscle, lung, liver, intestine proximal	L. Barbosa
SOT.70	15/03/2007	F	185.5	Costa	Vila Velha	Skeleton, teeth, lung, kidney, muscle, liver, intestine proximal, distal bowel	M. Araújo
SOT.72	06/04/2007	M	190	Morada do Sol	Vila Velha	Skeleton, teeth, brain, bone marrow, lung, muscle, intestine proximal, distal bowel	L. Serafim
SOT.73	09/04/2007	M	167	Regência	Linhares	Skeleton, teeth, lung, brain, kidney, liver, muscle, intestine proximal, distal bowel	M. Araújo
SOT.79	11/06/2007	UN	189	Guriri	São Mateus	Skeleton, teeth	I. Bianchi

Table 1. Continued...

Specimen	Collection date	Sex	Total length	Locality	City	Tissues samples stored	Responsible staff
SOT.83	12/01/2007	F	183	Regência	Linhares	Skeleton, teeth, muscle, kidney, liver, adipose, intestine proximal, distal bowel	I. Bianchi
SOT.84	12/10/2007	M	144.5	Regência	Linhares	Skeleton, teeth, liver, lung, adipose, kidney, intestine proximal, distal bowel	I. Bianchi
SOT.85	18/10/2007	M	151.5	Itapuã	Vila Velha	Skeleton, teeth, lung, kidney, adipose, liver, intestine proximal, distal bowel	M. Araújo
SOT.86	27/11/2007	F	192.5	Santa Cruz	Aracruz	Skeleton, teeth, lung, kidney, liver, muscle, adipose, intestine proximal, distal bowel	I. Bianchi
SOT.88	20/01/2008	F	151.5	Centro	Conceição da Barra	Skeleton, teeth, lung, kidney, muscle, liver, adipose, intestine proximal, distal bowel	I. Bianchi
SOT.92	08/03/2008	F	185	Manguinhos	Serra	Skeleton, teeth, kidney, muscle, lung, liver, adipose, intestine proximal, distal bowel	L. Serafim
SOT.93	10/03/2008	F	183	Jacaraípe	Serra	Skeleton, teeth	L. Serafim
SOT.94	28/03/2008	F	169	Regência	Linhares	Skeleton, teeth, liver, lung, kidney, muscle, adipose, intestine proximal, distal bowel	I. Bianchi
SOT.96	28/04/2008	M	190	Peracanga	Guarapari	Skeleton, teeth, lung, bone marrow, liver, muscle	I. Bianchi
SOT.99	21/08/2008	F	119	Regência	Linhares	Skeleton, teeth, muscle, kidney, adipose, liver, intestine proximal, distal bowel	L. Barbosa
SOT.103	08/12/2008	M	187	Solemar	Serra	Skeleton, teeth	L. Serafim
SOT.110	20/03/2009	UN	149	Setiba	Guarapari	Skeleton, teeth, adipose, liver, lung, muscle	L. Serafim
SOT.113	29/03/2009	M	165	Regência	Linhares	Skeleton, teeth, muscle, lung, kidney, liver, adipose, intestine proximal, distal bowel	I. Bianchi
SOT.115	03/05/2009	M	164	Areia Preta	Guarapari	Skeleton, teeth, muscle, liver, intestine proximal, distal bowel	L. Serafim
SOT.118	27/07/2009	M	165	Guaibura	Guarapari	Skeleton, teeth, liver, adipose, muscle, kidney, intestine proximal, distal bowel	L. Serafim
SOT 119	06/08/2009	M	180	Castelhanos	Anchieta	Skeleton, teeth, muscle, lung, kidney, liver, testicle, intestine proximal, distal bowel	L. Serafim
SOT.120	15/08/2009	M	129	Siribeira	Guarapari	Skeleton, teeth, muscle, liver, adipose, lung, kidney, intestine proximal, distal bowel	I. Bianchi
SOT 123	06/12/2009	M	140	Castelhanos	Anchieta	Skeleton, teeth, muscle, kidney, lung, adipose, intestine proximal, distal bowel	L. Barbosa
SOT.125	21/12/2009	M	161.3	Regência	Linhares	Skeleton, teeth, muscle, kidney, lung, adipose, intestine proximal, distal bowel	L. Serafim
SOT.131	17/04/2010	M	122	Mãe-Bá	Anchieta	Skeleton, teeth, liver, kidney, adipose, muscle, lung, intestine proximal, distal bowel	L. Serafim
SOT.133	07/06/2010	M	174	Itaipava	Itapemirim	Skeleton, teeth	L. Serafim

in a quick-action commercial decalcification agent containing HCl (RDO™) for periods between 3 h and 24 h, depending on the size of sections and on the degree pulpar cavities were filled. The ideal degree of decalcification was established when sections were completely flexible. Decalcified specimens were sectioned again parallel to the longest axis in a microtome-cryostat. Central sections were chosen so as to afford more accurate age readings. Sections were stained using Mayer's hematoxylin to reveal growth layers groups (GLGs). Readings were made in an optical microscope under 40x magnification.

Descriptive statistics was used for mean, maximum, minimum, and standard deviation of total length values. Animals were sorted by dental age as immature (≤ 6 years) and mature (≥ 7 years), and by sex. Inferential statistics included the calculation of growth parameters for TL and predicting the asymptote based on the Gompertz non-linear model, Y = ae[-e (b-cx)], where Y is the measured variable, a is the asymptote, b is the correction factor, c is the growth rate constant, and x is the age (Zullinger et al., 1984). The model was adjusted using the Curve Expert 1.4 software for Windows.

3. Results

The age of 44 *S. guianensis* specimens was estimated (see Figure 1). Values were between 0.5 year and 33 years (mean = 8.34, SD = 7.06). Most specimens (47%) were between zero and 6 years.

Age of immature males ranged from 1 year to 6 years (mean = 3.08, SD = 1.97), while mature males were between 8 and 23 years old (mean = 12.45, SD = 4.92). Immature females varied between 0.5 year and 4 years of age (mean = 2.5, SD = 1.32), and age of mature females ranged from 7 to 33 years (mean = 15.75, SD = 8.20) (as shown in Table 2).

The age-based TL growth curve constructed using the Gompertz model indicated that asymptotic lengths was reached at 182 cm, roughly in the 5-6 years age range (correction factor = -0.54, growth rate = 0.79, coefficient of determination, $R^2 = 0.82$) (see Figure 2).

The growth curve for TL (cm) and age (years) adjusted with the Gompertz model for male *S. guianensis* specimens indicated that asymptotic length was reached at approximately 176 cm (correction factor = 1.28, growth rate = 2.68, coefficient of determination, $R^2 = 0.71$) (see Figure 3). For *S. guianensis* females, asymptotic length was reached at 191 cm (correction factor = -0.44, growth rate = -0.54, coefficient of determination, $R^2 = 0.96$) (Figure 4).

Mean TL for immature males (≤ 6 years) was 166.11 cm (SD = 20.34). For mature males (≥ 7 years), mean TL was 190.18 cm (SD = 158.75). For immature and mature females mean TL was 158.75 cm (SD = 28.19) and 191.0 cm (SD = 7.12) (as shown in Table 3).

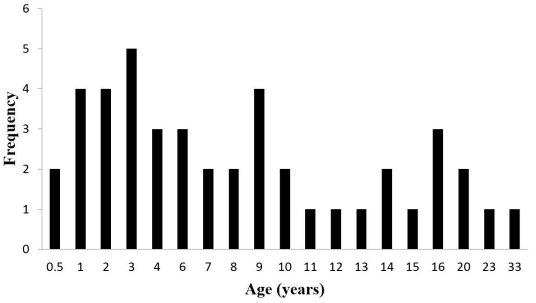

Figure 1. Age (years) frequency of *Sotalia guianensis* in the state of Espírito Santo, Brazil.

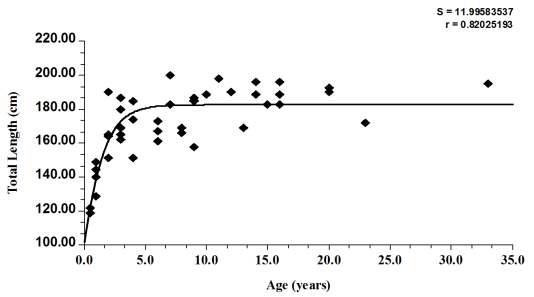

Figure 2. Growth curve adjusted with the Gompertz model for total length (cm) and age (years) for *Sotalia guianensis* specimens in the state of Espírito Santo, Brazil.

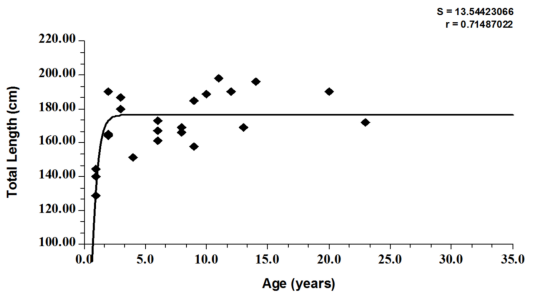

Figure 3. Growth curve adjusted with the Gompertz model for total length (cm) and age (years) for male *Sotalia guianensis* specimens in the state of Espírito Santo, Brazil.

Table 2. Maximum, minimum, mean, and standard deviation of age (years) of mature and immature male and female *Sotalia guianensis* specimens in the state of Espírito Santo, Brazil.

	Males		Female	
	Immature	**Mature**	**Immature**	**Mature**
Minimum	1	8	0.5	7
Mean	3.08	12.45	2.5	15.75
Maximum	6	23	4	33
Standard deviation	1.97	4.92	1.32	8.20

Table 3. Maximum, minimum, mean, and standard deviation of total length (cm) of mature and immature male and female *Sotalia guianensis* specimens in the state of Espírito Santo, Brazil.

	Males		Females	
	Immature	**Mature**	**Immature**	**Mature**
Minimum	129	158	119	183
Mean	166.11	180.18	158.75	191
Maximum	190	198	185	200
Standard deviation	20.34	13.68	28.19	7.12

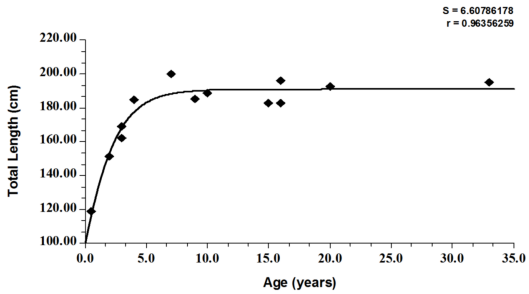

Figure 4. Growth curve adjusted with the Gompertz model for total length (cm) and age (years) for female *Sotalia guianensis* specimens in the state of Espírito Santo, Brazil.

4. Discussion

Previous studies reported lower age variation ranges for *S. guianensis* in Espírito Santo, Brazil, compared with the values obtained in the present research(mean age = 8.34 years, SD = 7.06, minimum = 0.5 year, maximum = 33 years). Ramos et al. (2000) analysed *S. guianensis* found in the north of the state of Rio de Janeiro, Brazil, and suggested that adults may reach the age of 30 years. For Rosas et al. (2003) *S. guianensis* may live for up to 35 years, though the oldest male observed in their study on the coast of the state of Paraná, Brazil, was 29 years old.

In the present study, age of males varied between 1 and 23 years, while for females the age range was 0.5 year (newly born) to 33 years. Di Beneditto and Ramos (2004) observed that age range was zero – 21 years for males and 0.5 – 33 years for females in northern Rio de Janeiro state, Brazil. Lailson-Brito et al. (2010) reported that maximum age for *S. guianensis* was 14 years for one male in Guanabara Bay, 13 years for one male in Sepetiba Bay, and 20 years for one female in Paranaguá Bay, all of which are in Brazil. These values are similar, and suggest higher life expectancy for females of the species.

Rosas et al. (2003) believe that young *S. guianensis* individuals as well as those in the process of reaching sexual maturity (between 4 and 6 years of age) are more susceptible to be captured. Similarly, Di Beneditto and Ramos (2004) reported that males of up to 6 years of age account for 80% of *S. guianensis* captured, and suggest that individuals at the beginning of the sexual maturation stage are more vulnerable. For the authors, such vulnerability may be associated with behaviour pattern and composition of populations. In the present study, the age group to which the highest number of animals (47%) belonged was zero – 6 years, which confirms that younger animals at the sexual development stage are more vulnerable to being accidentally captured by fish nets. Significant social organization issues may lead to differential vulnerability based on age groups and sex (IWC, 1994). The excessive decline in populations could indicate a change in the ecosystem (Taylor, 1997). The fact that most animals accidentally captured were at reproductive stage may play a role in population decline, though no in-depth study has evaluated the risks *S. guianensis* is exposed to. Due to the threats faced by the specimens, it has been has suggested that the species should be considered vulnerable, in light of the threats it has had to face (Rosas, 2006).

Using the Von Bertalanfy method, Schmiegelow (1990) estimated that TL asymptote of *S. guianensis* was 182.6 cm in the Brazilian states of São Paulo and Paraná. Santos et al. (2003) used the same method to analyse *S. guianensis* specimens from the same states and reported maximum TL of 186.4 cm. Rosas et al. (2003) analysed *S. guianensis* from the state of Paraná using the Von Bertalanfy method and observed that males and females reached 186.4 cm and 177.3 cm in TL, respectively. However, the authors noticed that growth of males may be discontinuous at the age of 5 years, with a secondary growth process at puberty, which required that separate growth curves for sexes. The Gompertz model is often employed in small cetacean morphology studies (Fernandez and Hohn, 1998; Ramos et al., 2000, 2010; Di Beneditto and Ramos, 2004). Di Beneditto and Ramos (2004) used the Gompertz model to conclude that maximum TL was 191 cm for *S. guianensis* in northern Rio de Janeiro, a value that is higher than that observed in the other study sites mentioned. Such difference in asymptotic TL may be the result of regional variation between populations. However, in the present study the asymptotic TL value was near the mean value, when compared with the other regions surveyed. TL of 44 *S. guianensis* individuals varied between 119 cm ad 200 cm, with mean of 174.10 cm and SD of 20.51 cm.

Ramos et al. (2010) reported that TL of *S. guianensis* from the state of Espírito Santo varied between 175.0 and 222.0 cm for males and 166.0 and 184.5 cm for females. For mature individuals TL varied between 167.0 and 222.0 cm, similarly to the values observed in the present study. In the north of the state of Rio de Janeiro, TL of males varied between 86.0 and 200.0 cm, while TL of females ranged from 117.5 and 198.0 cm. TL of mature individuals varied

between 161.0 and 200 cm. The specimens evaluated in the state of São Paulo presented mean TL values that were shorter than those of *S. guianensis* from Rio de Janeiro and Espírito Santo (Ramos et al., 2010). As observed by Ramos et al. (2010), length obeys a clinal gradient that increases with latitude and, under specific conditions, factors other than heat conservation may affect geographic variation, such as nutrition requirements.

Variations in TL of *S. guianensis* were observed across its distribution range. The largest individual observed was a female found stranded on the coast of Espírito Santo measuring 206.0 cm (Barros, 1991). Di Beneditto and Ramos (2004) recorded maximum TL of 200 cm for a male and 198 cm for a female in the north of Rio de Janeiro state. Lailson-Brito et al. (2010) observed that maximum TL of *S. guianensis* in Guanabara Bay was 191 cm, while TL of animals from the Sepetiba and Paranaguá bays were 195 cm and 198 cm, respectively. However, Barbosa and Barros (2006) estimated TL values and declared that maximum TL for the species would be 222 cm. For the state of Espírito Santo, maximum TL was observed in the present study were 200 cm for females and 198 cm for males, though age of individuals was not assessed. TL data obtained here were similar to those cited above.

The *S. guianensis* individuals found on the coast of the state of Espírito Santo, Brazil had higher mean TL than animals surveyed in other locations. Variation in TL between animals of different regions was discussed by Cunha et al. (2010), who described changes in the parameter across animals of various geographic regions using DNA analysis that indicated distinct *S. guianensis* populations in the states of Pará, Ceará, Rio Grande do Norte, Bahia, Espírito Santo, and in the southeast and south states (Rio de Janeiro, São Paulo, Paraná e Santa Catarina). Similarly, Caballero et al. (2006) pointed to the differences between Caribbean and South and Central American specimens. However, the same authors observed small genetic differences between populations living on the Brazilian coast (Caballero et al., 2010).

Most morphometric studies with cetaceans used cranium and skeleton parameters (Perrin et al., 2003). Little research has used external morphological parameters, possibly due to the difficulty to obtain samples. Also, some characters are affected by changes occurred after the animal died, especially due to decomposition (Wang et al., 2000).

Age estimates based on GLGs are a useful tool in the determination of sexual maturity and development stage of individual. In like manner, studies about the degree of morphological, genetic, or behavioral changes in cetaceans afford to better understand the evolutive processes underwent by one species, and are useful in the management of populations (Wiig, 1992). Younger animals are more susceptible to being captured accidentally, especially males, which highlights the importance of studies and of monitoring programs in conservation efforts for this species.

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