A note on strandings of Bryde's whales (*Balaenoptera edeni*) in the southwestern Atlantic

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ABSTRACT

This study analysed 74 records of Bryde's whale strandings in jurisdictional Brazilian waters in order to further understanding of strandings in the region. Collation of records published in the media (newspapers, magazines, TV, online sources) and in peer-reviewed articles revealed 74 documented strandings between 1972 and 2015 along the coasts of Rio Grande do Sul, and Rio de Janeiro, Bahia and Maranhão states. Statistically significant differences were found between the frequencies of strandings in relation to Brazilian regions ($\chi^2 = 103.17$), with the highest abundance found in the Southeast region (71.62%). Statistically significant differences were also observed between stranding frequency and sexual maturity ($\chi^2 = 12.31$), with a higher abundance for sexually mature females (54.25%). No statistically significant difference between the stranding frequency in relation to seasonality ($\chi^2 = 2.8$) was observed. No statistically significant difference between stranding frequency for males and females was found ($\chi^2 = 3.12$). A simple linear regression showed an increasing trend of Bryde's whale strandings from the 1980s onwards, possibly due to population growth, increased monitoring throughout the Brazilian coast, and/or an increase in anthropogenic threats.

KEYWORDS: BRAZIL; BRYDE´S WHALE; STRANDINGS

INTRODUCTION

The Bryde´s whale (*Balaenoptera edeni*) is a predominantly tropical species, sighted in Brazil in both coastal and oceanic areas (Andriolo *et al.*, 2010; Figueiredo *et al.*, 2014; Lodi *et al.*, 2015; Siciliano *et al.*, 2004), especially in the southeast of the country (de Moura and Siciliano, 2012; Lodi and Borobia, 2013). This study collates records on Bryde's whale strandings in order to obtain a general understanding of the species in Brazil, and specifically to: (a) verify if a certain region in the country displays a higher stranding frequency; (b) assess the seasonality of the strandings; (c) compare the sexual frequency of stranded specimens; (d) characterise the sexual maturity of stranded animals; and (e) determine possible trends in the stranding incidences in recent decades.

The occurrence and reporting of cetacean stranding events can be influenced by a number of factors, and reported trends are often questioned. The effects of monitoring coverage and environmental variations, such as tides, winds and ocean currents (which can carry carcasses to different beach locations), lead to debates on whether stranding records do in fact represent the abundance of a certain population (Meager and Limpus, 2014; Meager and Sumpton, 2016; Peltier *et al.*, 2014). However, strandings data can be used as an additional tool to evaluate possible patterns related to the general distribution of a species, as records may reflect the occurrence frequency in a given area (Maldini *et al.*, 2005). Strandings data can also verify whether the gathering of records has increased in recent times and thus inform future conservation efforts (Lima *et al.*, 2006).

METHODS

A literature search using Google Scholar[2], SciELO[3] and The Web of Science[4] databases was conducted during the months of July–November 2015 using the following search terms: 'baleen-de-bryde', '*Balaenoptera edeni*', '*Balaenoptera brydei*', 'strandings', and 'Brazil'. Results were then manually sorted and only articles relevant to the study were selected. This research was complemented with items from online communication channels such as local newspaper reports (O Globo, Zero Hora, Correio do Povo), and Google[5] searches using the terms 'baleia-de-bryde', 'strandings' and 'Brazil'. Only records containing photographs or videos of diagnostic features (i.e. rostral ridges) were used to confirm positive identification of the species. In total, 74 records documenting strandings of Bryde's whales between 1972 and 2015 were obtained (see Table 1).

Strandings by region

Records were grouped regionally from South to North by date and according to the Brazilian regional classification (South, Southeast and Northeast). Records were then plotted on a map with the aid of a geographic projection using DATUM SIRGAS 2000, available with the software package ArcMap (ArcGis Desktop 10.5 Esri) (Fig. 1). Where geographic coordinates of strandings were not available, coordinates were estimated from the central point of the cited location. These coordinates were based on the geographical

[2] *https://scholar.google.com* [Accessed 22 August 2015].
[3] *https://www.scielo.org/* [Accessed 15 September 2015].
[4] *http://wokinfo.com/* [Accessed 2 October 2015].
[5] *https://www.google.com.br* [Accessed 20 October 2015].

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Table 1
Strandings records of Bryde's whales in the south, southeast and northeast of Brazil between 1972 and 2015 (n = 74).

Data/Year	Locality and coordinates	Sex	Total length (m)	References
SOUTHERN REGION				
Rio Grande do Sul				
August 1989	Rio Grande ~32°01'S, 52°05'W	–	15	Zerbini *et al*., 1997
22.12.1994	Praia de Tramandaí 29°59'S, 50°07'W	M	10.8	Zerbini *et al*., 1997
29.02.1996	Praia de Tramandaí 29°59'S, 50°07'W	M	4	Zerbini *et al*., 1997
20.01.2005	30°13'S, 50°13'W	–	–	Pastene *et al*., 2015
21.01.2005	30°20'S, 50°16'W	–	–	Pastene *et al*., 2015
25.04.2014	Praia do Cassino, Rio Grande ~ 32°11'S, 52°09'W	–	11	Torales, 2014
16.11.2014	Praia Atlântida Sul ~ 29°52'S, 54°04'W	–	~ 6	Marchi, 2014
Santa Catarina				
17.09.1993	Laguna 25°25'S, 48°00'W	F	8.8	Zerbini *et al.*, 1997
January 1994	Florianópolis 27°35'S, 48°33'W	–	–	Zerbini *et al*., 1997
29.02.1996	Praia da Península, Barra Velha ~26°38'S, 48°40'W	–	12.6	Soto *et al*., 2001 in SIMMAM
20.01.2005	Praia da Cigana, Laguna 25°25'S, 48°00'W	–	13	Dalcin, 2009
21.01.2005	Praia de Itapiruba, Imbituba 28°19'S, 48°42'W	–	–	Moreira *et al*., 2010
23.06.2014	Praia do Molhe, São Francisco do Sul 26°54'S, 48°38'W	–	–	Papa-Berbigão, 2014
13.10.2015	Praia do Molhe, São Francisco do Sul 26°54'S, 48°38'W	–	~ 9	Pereira, 2015
Paraná				
29.06.1983	Ilha Superagui 25°25'S, 48°00'W	F	13	Bittencourt, 1983
28.04.1993	Guaratatuba 25°53'S, 48°34'W	F	3.9	Zerbini *et al*., 1997
30.09.1993	Ilha Superagui 25°25'S, 48°00'W	M	14	Zerbini *et al*., 1997
SOUTHEAST REGION				
São Paulo				
August 1972	Cananéia 25°00'S, 47°55'W	–	12.5	Zerbini *et al*., 1997
1986	Itanhaém 24°17'S, 46°74'W	–	–	Zerbini *et al*., 1997
November 1994	Ilha Comprida 25°05'S, 47°59'W	–	14	Siciliano *et al*., 2004
03.09.1996	Ilha do Cardoso 25°05'S, 47°59'W	F	14	Siciliano *et al*., 2004
30.01.1997	Ilha Comprida 24°54'S, 47°48'W	–	12	Siciliano *et al*., 2004
07.12.1997	Peruíbe 24°19'S, 47°00'W	–	15	Siciliano *et al*., 2004
18.06.1998	Guarujá 23°59'S, 46°14'W	M	12.4	Siciliano *et al*., 2004
22.09.1998	Praia Grande 24°10'S, 43°15'W	–	14	Siciliano *et al*., 2004
09.04.1999	Monguaguá 24°05'S, 46°37'W	–	12	Siciliano *et al*., 2004
21.08.1999	Praia Grande 24°10'S, 43°15'W	–	12.2	Siciliano *et al*., 2004
24.07.2000	Praia do Félix, Ubatuba 23°22'S, 44°54'W	F	14	Siciliano *et al*., 2004
April 2001	Juréia 24°40'S, 47°20'W	M	15	Siciliano *et al*., 2004
September 2002	Ilha do Cardoso 25°05'S, 47°59'W	M	12	Siciliano *et al*., 2004
13.10.2005	São Sebastião 23°40'S, 45°25'W	M	12	Santos *et al.*, 2010

Table 1 (*continued*).

Data/Year	Locality and coordinates	Sex	Total length (m)	References
09.06.2006	Praia do Boqueirão, Ilha Comprida 25°02'S, 47°53'W	M	8	Santos *et al*., 2010
12.08.2006	Praia de Ilha Comprida, Ilha Comprida 24°58'S, 47°50'W	–	12	Santos *et al.*, 2010
23.10.2006	São Sebastião 23°35'S, 45°12'W	M	12.8	Santos *et al.*, 2010
20.07.2007	Peruíbe 24°16'S, 46°55'W	–	12	Moura and Siciliano, 2012
12.08.2007	Praia Grande 24°01'S, 46°27'W	F	4.8	Santos *et al.*, 2010
08.03.2008	Guarujá 24°01'S, 46°17'W	M	8.4	Moura and Siciliano, 2012
27.04.2009	Praia da Ilha Comprida, Ilha Comprida 24°14'S, 47°32'W	–	9	Moura and Siciliano, 2012
25.07.2009	Guarujá 23°59'S, 46°12'W	M	13	Santos *et al*., 2010
13.06.2010	Mongaguá 24°05'S, 46°37'W	F	7	Moura and Siciliano, 2012
23.11.2013	Praia da Barra do Ribeira, Iguape ~ 24°37'S, 47°19'W	M	13.5	Domingues, 2013
20.10.2015	Praia do Peruíbe ~ 24°19'S, 46°59'W	–	14.3	Moura and Siciliano, 2012
20.10.2015	Ilha do Tamanduá, Caraguatatuba ~ 23°36'S, 45°16'W	M	12	G1, O Globo/Vale do Paraíba and Região, 2015
Rio de Janeiro				
29.01 1983	Baía de Guanabara 22°56'S, 43°15'W	M	7.1	Geise e Borobia, 1988
03.04.1989	Angra dos Reis 23°00'S, 44°18'W	M	10.6	Zerbini *et al*., 1997
07.04.1995	Saquarema 22°56'S, 42°30'W	F	8	Zerbini *et al*., 1997
18.06.1998	Quissamã 22°15'S, 41°30'W	F	8	Siciliano *et al*., 2004
22.08.1998	Rio de Janeiro 22°58'S, 43°10'W	–	10.8	Siciliano *et al*., 2004
11.12.2001	Barra de São João 22°35'S, 42°00'W	–	~ 9	Siciliano *et al.*, 2004
30.01.2003	Maricá 22°59'S, 43°00'W	F	12	Siciliano *et al*., 2004
December 2003	Proximidade da Ilhas das Cagarras (Carcaça flutuando) 23°01'S, 43°12'W	–	–	Lodi and Tardin, 2014
26.02.2004	Lagoa do Paulista, Quissamã 23°14'S, 41°32'W	–	9.5	Moura and Siciliano, 2012
20.09.2004	Recreio dos Bandeirantes 23°01'S, 43°28'W	M	–	Lodi and Tardin, 2014
23.01.2005	Praia do Abricó, Rio das Ostras 22°31'S, 41°56'W	–	–	Moura and Siciliano, 2012
14.02.2005	Maricá 22°58'S, 41°56'W	M	15	Moura and Siciliano, 2012
03.08.2005	Proximidades da Ilha Redonda (Carcaça flutuando) 23°04'S, 43°12'W	–	–	Lodi and Tardin, 2014
06.08.2005	Barra da Tijuca 23°07'S, 43°21'W	–	11	Moura and Siciliano, 2012
03.09.2005	Figueira, Arraial do Cabo 22°56'S, 43°11'W	–	–	Moura and Siciliano, 2012
28.09.2006	Praia de Unamar, Cabo Frio 22°37'S, 41°59'W	M	12	Moura and Siciliano, 2012
30.09.2006	Praia do Pecado, Macaé 22°24'S, 41°48'W	M	12	Moura and Siciliano, 2012
14.02.2007	Praia de Itaipuaçu, Maricá 22°58'S, 42°59'W	M	14	Moura and Siciliano, 2012
18.08.2007	Praia Grande, Arraial do Cabo 22°57'S, 42°03'W	–	–	Moura and Siciliano, 2012
15.04.2008	Figueira, Arraial do Cabo 22°56'S, 42°09'W	–	–	Moura and Siciliano, 2012
September 2008	Ilha de Águas Lindas, Itacuruçá, Mangaratiba 22°56'S, 43°54'W	–	10	Moura and Siciliano, 2012
11.10.2008	Praia do Afonso, Arraial do Cabo 22°57'S, 42°05'W	–	14.1	Moura and Siciliano, 2012

Table 1 (*continued*).

Data/Year	Locality and coordinates	Sex	Total length (m)	References
14.10.2008	Praia das Palmeiras, Caraguatatuba 23°40'S, 45°25'W	–	7	Moura and Siciliano, 2012
08.03.2010	Lagoa Comprida, Jurubatiba, Macaé 23°16'S, 41°39'W	M	7.17	Moura and Siciliano, 2012
30.10.2010	Praia de Carapebus 22°15'S, 41°36'W	F	8.8	Moura and Siciliano, 2012
09.03.2011	Praia do Visgueiro, Quissamã 22°13'S, 41°31'W	–	8	Moura and Siciliano, 2012
20.03.2012	Proximidades do Vidigal (Carcaça flutuando) 22°59'S, 43°14'W	–	–	Lodi and Tardin, 2014
NORTHEAST REGION				
Bahia				
30.09.1981	15 km do Rio Paraguaçu, Maragogipe, Baía de Todos os Santos 12°48'S, 38°55'W	F	14	Lima *et al*., 2006
Maranhão				
1991	Praia do Ciumal, Delta do Parnaíba ~ 2°41'S, 42°08'W	–	10	Zerbini *et al*., 1997
1996	Ilhas Canárias, Delta do Parnaíba ~ 2°41'S, 42°08'W	–		Zerbini *et al*., 1997
1999	Ilha do Caju, Delta do Parnaíba ~ 2°41'S, 42°09'W	–	–	Magalhães *et al*., 2008

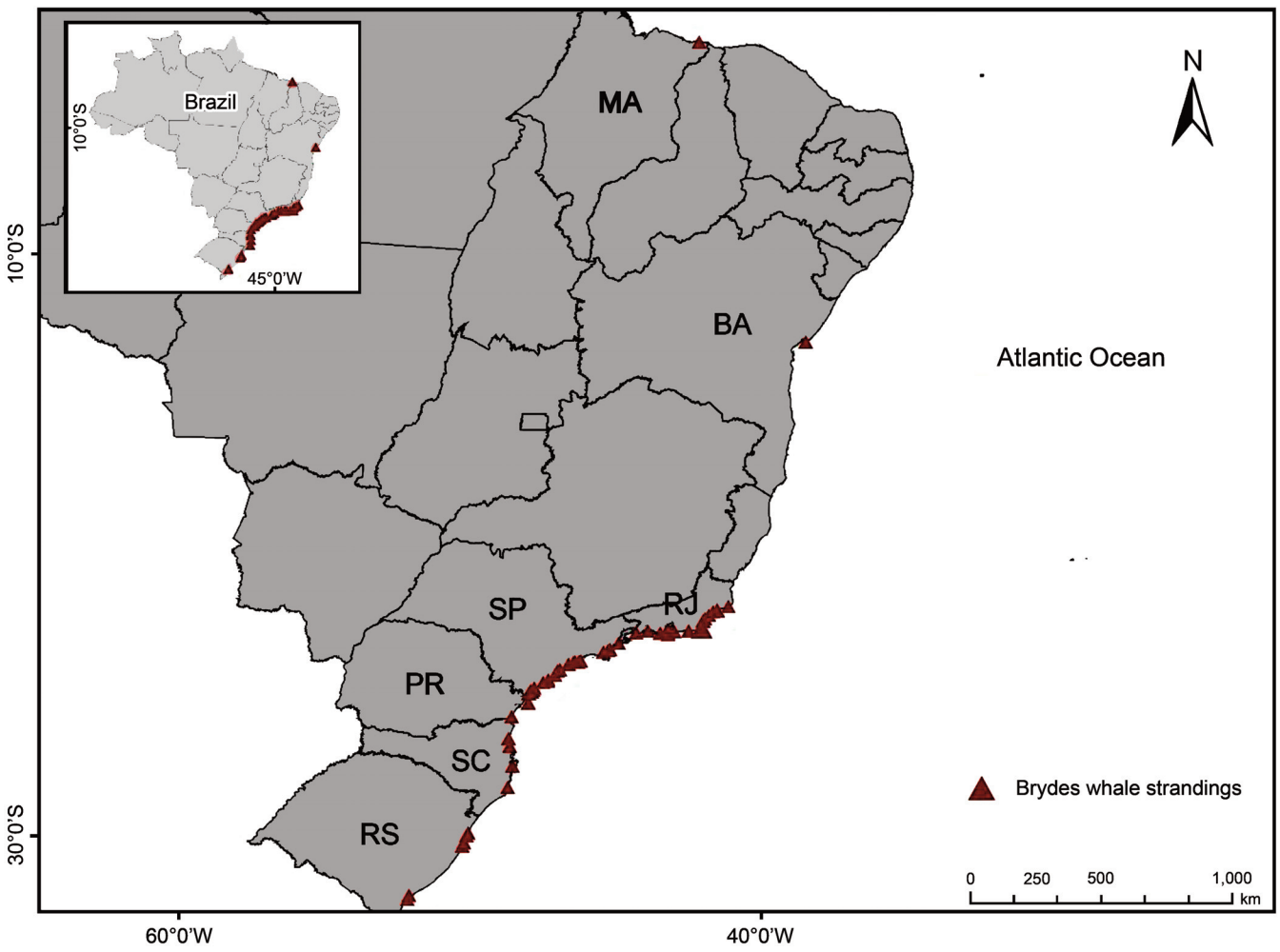

Fig. 1 Bryde´s whale strandings in Brazil between 1972 and 2015: Maranhão (MA); Bahia (BA); Rio de Janeiro (RJ); São Paulo (SP); Paraná (PR); Santa Catarina (SC); and Rio Grande do Sul (RS).

coordinates provided by WGE98 (*Google Earth* software) and were also plotted using ArcMap (ArcGis Desktop 10.5 Esri) to standardise the coordinates of all compiled records.

Seasonality
To assess potential seasonality trends data were categorised according to four seasons: January to March (summer); April to June (autumn); July to September (winter); and October to December (spring) (de Moura and Siciliano, 2012).

Sexual maturity
To categorise the sexual maturity of the stranded specimens, Bryde's whales were classified as juvenile (≤8m), sexually immature (> 8m and ≤ 11.2m) and sexually mature (> 11.2m) using two cetacean identification guides (Jefferson *et al.*, 2008; Kato and Perrin, 2009).

Sex
Gender was determined when the whale position allowed for an overview of the ventral region or when the carcasses were dissected, according to documented records published in the articles of de Moura and Siciliano (2012), Santos *et al.* (2010) and Siciliano *et al.* (2004) or from local newspaper reports. When the sex of the specimens was not documented from morphological evidence due to the advanced decomposition of the carcass, gender was considered undetermined. The Chi-square test was not applied when sex was undetermined.

Statistical analyses
A Chi-square test was used to attest significant differences between observed and expected frequencies, with a significance level set at $\alpha = 0.05$. The test was applied to verify potential differences between strandings' frequency in Brazilian regions, seasonality, sex and sexual maturity of the specimens. A simple linear regression was used to determine trends in stranding incidences between 1970 and 2010, using the *STATISTICA* software package.

RESULTS AND DISCUSSION

Strandings by region
A total of 74 Bryde's whale strandings were documented in Brazil between 1972 and 2015 in the states of Rio Grande do Sul and Rio de Janeiro, Bahia and Maranhão. The highest frequency of strandings (71.6%, n = 53), was observed in the Brazilian southeast region. The most representative states in this region were Rio de Janeiro with 36.5% (n = 27), and São Paulo with 35.1% (n = 26) The south region recorded (23% n = 17) with the states of Rio Grande do Sul (9.4% n = 7), Santa Catarina (9.4% n = 7) and Paraná (4% n = 3). The Northeast region presented a frequency of (5,4% n = 4) with the states of Maranhão (4% n = 3) and Bahia (1.3% n = 1). A statistically significant difference of strandings frequency was observed among regions southeast, south and northeast ($\chi^2 = 103.17$; SD = 0.3430 $p < 0.05$) (de Moura and Siciliano, 2012; Gonçalves and Andriolo, 2006; Siciliano *et al.*, 2004; Zerbini *et al.*, 1997). Conversely, the number of strandings documented in the northeast and north regions was either low or non-existent. This was probably related to the low monitoring efforts carried out in these regions as this species presents a predominantly tropical distribution. Bryde's whales associate with regions of upwelling and consequently, with areas of high productivity (Gallardo *et al.*, 1983; Kerosky *et al.*, 2012; Pardo and Palacios, 2006; Tershy *et al.*, 1990). Examples of upwelling regions are the Chilean coast (Gallardo *et al.*, 1983), South Africa (Best, 2001), the tropical East of the Pacific Ocean (Palacios, 2003), the Santa Marta region of the Caribbean and the recess of Southern California (Kerosky *et al.*, 2012), while productive regions include the Ballenas Channel in the Gulf of California (Tershy *et al.*, 1990), in the continental shelf division and in the northeastern Gulf of Mexico (Davis *et al.*, 1998).

Sightings
Sighting records for this species are also higher in the Brazilian Southeast region (Gonçalves and Andriolo, 2006; Lodi and Borobia, 2013; Siciliano *et al.*, 2004; Zerbini *et al.*, 1997), especially within the state of Rio de Janeiro. This may be related to the abundance and availability of food resources in the productive waters of the region, such as sardines (*Sardinella brasiliensis*), one of the main dietary items of this species (de Moura and Siciliano, 2012; Figueiredo *et al.*, 2014).

Seasonality
Seasonality was evaluated for 94.6% (n = 70) of the strandings records. The highest stranding frequency was observed in winter (32.8%), followed by summer (25.7%). The highest number of records was observed in August (n = 11) and September (n = 11). No statistically significant seasonality was observed for strandings frequency ($\chi^2 = 2.8$, SD = 0.0487, $p > 0.5$). The results observed here corroborate other studies which also report an absence of seasonal stranding patterns, despite higher records in winter (de Moura and Siciliano, 2012; Siciliano *et al.*, 2004). The higher frequency of winter strandings could be explained by the combination of south and southwest winds, particularly common in winter, and intense ocean currents bringing carcasses to Brazilian coasts (de Moura and Siciliano, 2012).

Sex
Sex was determined for 43.2% (n = 32) of the strandings records. Frequencies of 65.6% (n = 21) males and 34.4% (n = 11) females were observed. Although higher frequencies of males were observed, this was not statistically significant ($\chi^2 = 3.12$, SD = 0.2209, $p > 0.10$). This can be explained by the high number of records where sex was not identified, probably due to the decomposition state of the carcasses. The findings of this study support those of Siciliano *et al.* (2004), de Moura and Siciliano (2012) and (Santos *et al.*, 2010), which also indicate a higher frequency of male strandings in Brazil.

Sexual maturity
Data on the sexual maturity of stranded specimens were available in 79.7% (n = 59) of the evaluated strandings records. The total length of the individuals ranged from 3.8m to 15m. Juveniles presented a frequency of 20.3% (n = 12), followed by sexually immature (25.4%, n = 15) and mature

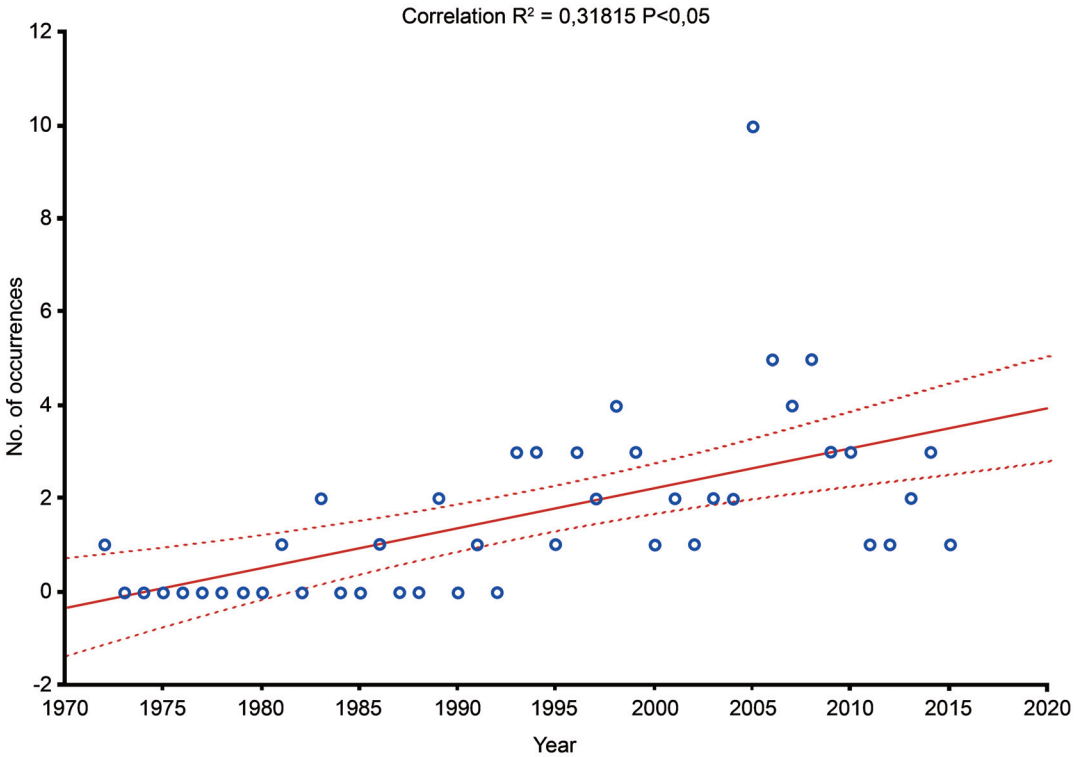

Fig. 2 Simple linear regression of the number Bryde's whales stranded in Brazil between 1972 and 2015.

(54.3%, n = 32) individuals. A statistically significant different strandings frequency was found among sexual maturity categories ($\chi^2 = 12.31$, SD = 0.1829, $p < 0.05$). The highest prevalence of juveniles (n = 12, ≤8m) was observed in the summer and autumn, with four records in March and four in June. Juvenile sightings were also recorded in Búzios in the autumn (Figueiredo *et al.*, 2014) and in Cabo Frio in the summer (de Moura and Siciliano, 2012). Regarding sexually mature specimens (> 11.2m), 32 records were found, with a higher prevalence in the winter and spring, mainly in July (three records) and October (eight records). The preliminary results found here suggest a need for further investigation into the still unknown reproductive aspects of Bryde's whales in Brazil.

Incidences of strandings

Although the use of a simple linear regression does not allow for extrapolations, a positive relationship was observed between the number of strandings between 1972 and 2015 ($R^2 = 0.31815$; $p < 0.05$) (Fig. 2). A trend towards an increase of Bryde's whale strandings from the 1980s onwards was identified, allowing for the prediction that the increase may continue. This can be related to a number of factors, including: (a) population growth due to the protection of the species after the end of commercial whaling, as has occurred in populations of southern right whales (*Eubalaena australis*) (Groch *et al.*, 2005) and humpback whales (*Megaptera novaengliae*) (Zerbini et al., 2010); (b) an increased monitoring effort along the Brazilian coast; and/or (c) increased anthropogenic threats. Potential threats to this species include collisions with ships (Lodi *et al.*, 2015; Stockin *et al.*, 2008; Van Waerebeek *et al.*, 2007), bycatch (Lodi *et al.*, 2015), and noise and chemical pollution (Barreto *et al.*, 2011).

Effective monitoring of strandings data, such as that used in this study, can inform management and conservation actions, and further studies could also improve understandings of Bryde's whale macroecology in the region. In addition, a higher number of stranded animal biopsies would further clarify the taxonomic status of the Bryde's whale in Brazil and contribute to the determination of whale stocks.

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