EVIDENCE FOR NORTHWARD EXTENSION OF THE WINTER RANGE OF MAGELLANIC PENGUINS ALONG THE BRAZILIAN COAST

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It has been reported that the winter distribution of Magellanic Penguin *Spheniscus magellanicus* may have extended northward along the Atlantic coast of South America during the last decade (Boersma 1997, 2008; Schiavini *et al.* 2005). Although breeding in Argentina as far south as Tierra del Fuego, Magellanic Penguins are known to move north to waters off the Brazilian coast, travelling up to 2 700 km away from their colonies during the non-breeding season (Ruppolo *et al.* 2012). Individuals reach southern and southeastern Brazil from March to September, but rarely travel as far north as Rio de Janeiro (21˚S) (Boersma *et al.* 1990). Herein, we present information to confirm the supposition that this species now occurs much farther north in Brazil than it did formerly. We do this by presenting data on the number of Magellanic Penguins that have been logged at Brazilian animal and wildlife rehabilitation centers from 2000 to 2010.

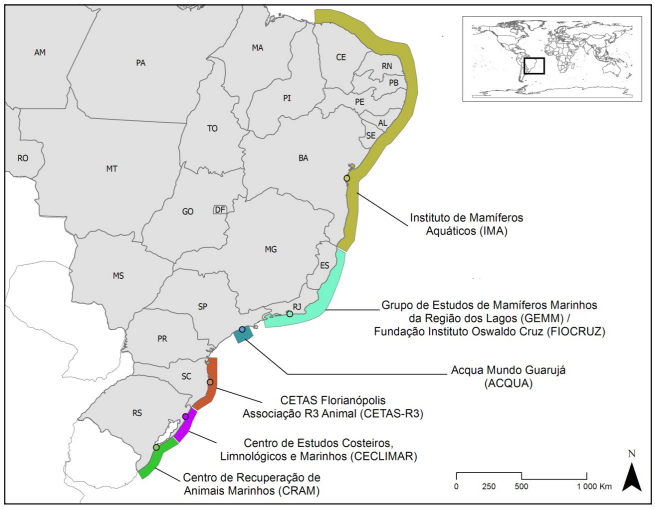

Fig. 1. Locations and areas of coverage of the institutions reporting Magellanic Penguins. The coastal states from which data were derived are abbreviated as follows, south to north: Rio Grande do Sul (RS), Santa Catarina (SC), Paraná (PR), São Paulo (SP), Rio de Janeiro (RJ), Espírito Santo (ES), Bahia (BA), Sergipe (SE), Alagoas (AL), Pernambuco (PE), Paraíba (PA), Rio Grande do Norte (RN), and Ceará (CE).

STUDY AREA AND METHODS

Seven of 14 institutions involved in Magellanic Penguin recording and rehabilitation in Brazil participated in this study. Associated workers logged dead specimens or rehabilitated penguins between 2000 and 2010, from Rio Grande do Sul State (29°57′S, 50°11′W) in southern Brazil to Ceará State (2°52′S, 41°16′W) in northern Brazil, covering approximately 5 000 km of coastline (Fig. 1, Table 1). We acquired these data via a survey submitted to the seven institutions.

Data collection by the institutions did not follow a uniform method for counting the number of Magellanic Penguins encountered. For example, some organizations monitored beaches every week, while others did so only a few times a year. In addition, some organizations recorded only live animals, whereas others recorded both live and dead animals. Therefore, we attempted to compensate for this irregular coverage by dividing the frequency of penguins for each state by the total number of penguins on the whole coast (frequency per state = number of penguins per state/total number on the coast). To assess whether ocean climate explained any of the annual variation in penguin encounter rate, the number of animals found each year was correlated with the Multivariate El Niño-Southern Oscillation (ENSO) Index (MEI) (www.esrl.noaa.gov/psd/enso/mei). In addition, a Wilcoxon test was used to compare the number of individuals encountered during ENSO (2002, 2004, 2006, 2008 and 2010) versus non-ENSO years (2000, 2001, 2003, 2005, 2007 and 2009). All statistical tests were performed using Number Cruncher Statistical System (NCSS) software (Hintze 2013).

RESULTS AND DISCUSSION

A total of 5404 Magellanic Penguins were logged at the seven Brazilian rehabilitation centers during 2000–2010, all during the austral autumn and winter (May to September). However, the majority of penguins (60%) were recorded in 2008, indicating that it was an atypical year.

A northward extension of the species' winter range is indicated in the data. Some northern states (Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas and Sergipe) had never recorded Magellanic Penguins before 2008, but have registered them since. Bahia recorded 1 630 individuals in 2008, the highest number ever recorded in a single year in any Brazilian state. Although Magellanic Penguins had been encountered on the Bahia coast previously, the number of individuals had typically been low (six individuals in 2000, one in 2003, and five in 2004).

How do we explain the northern extension of range for a species adapted to cold water? Many authors believe that the penguins migrate north to follow anchovy (*Engraulis anchoita*) shoals. However, García-Borboroglu *et al.* (2010) reported that the abundance of anchovies along the Brazilian coast is low because of oceanographic conditions and that the penguins that occur there probably feed on other fish, such as sardines (*Sardinella brasiliensis*). The Technical Relatory of Fishery in Brazil (2006; see also Castello 1998) noted that anchovies are found only in waters off the states of Rio Grande do Sul and Santa Catarina but that sardines are found farther north (São Paulo, Rio de Janeiro, Espírito Santo and Bahia), where the penguins have been recorded. Adding to the complexity, studies examining the diet of Magellanic Penguins on the Brazilian coast show that these birds mainly eat squid and crustaceans (Fonseca *et al*. 2001, Pinto *et al.* 2007, Baldassin *et al.* 2010). Thus, searching for anchovy schools does not appear to be the main reason that penguins move northward along the Brazilian coast.

TABLE 1
Geographic locations of participating rehabilitation institutions that provided data for this study

Institution	Latitude	Longitude
Instituto de Mamíferos Aquáticos (Salvador, BA)[a]	13°16′S	38°29′W
Fundação Oswaldo Cruz (Rio de Janeiro, RJ)	22°57′S	43°16′W
Grupo de Estudos de Mamíferos Marinhos da Região dos Lagos (Rio de Janeiro, RJ)	22°57′S	43°16′W
Acqua Mundo - Aquário do Guarujá (Guarujá, SP)	24°0′S	46°15′W
CETAS Florianópolis / Associação R3 Animal (Florianópolis, SC) [a]	27°38′S	48°28′W
Centro de Estudos Costeiros, Limnológicos e Marinhos (Imbé, RS) [a]	29°57′S	50°6′W
Centro de Recuperação de Animais Marinhos (Rio Grande, RS)	32°2′S	52°5′W

[a] No data were available before 2008.

Others factors besides availability of specific prey appear to be involved in the northward movements of Magellanic Penguins, including changes in oceanic currents, especially during ENSO (Mäder *et al.* 2010). Not surprisingly, the correlation between the MEI index and the number of individuals on the Brazilian coast was very weak ($r^2 = 0.10$), but the Wilcoxon test showed a significant difference between the number of individuals that arrived at the Brazilian coast in ENSO (2000, 2002, 2004, 2006, 2008 and 2010) versus non-ENSO years (2001, 2003, 2005, 2007 and 2009) ($z = 2.19$; $P = 0.014$) (Figs. 2 and 3). This outcome was similar when the 2008 year was excluded. Therefore, changes in ocean climate seem to be involved in the northward occurrence of Magellanic Penguins in an either-or scenario, at least in regard to ENSO. During El Niño, the distribution of cold water along the Brazilian coast changes: the cold, nutrient-rich Falkland Current penetrates more intensively over the southeast Brazilian continental shelf (Evangelista et al. 2007, Silva et al. 1996), seemingly encouraging Magellanic Penguins' northward movement. How prey availability may be involved is a subject that requires much additional investigation.

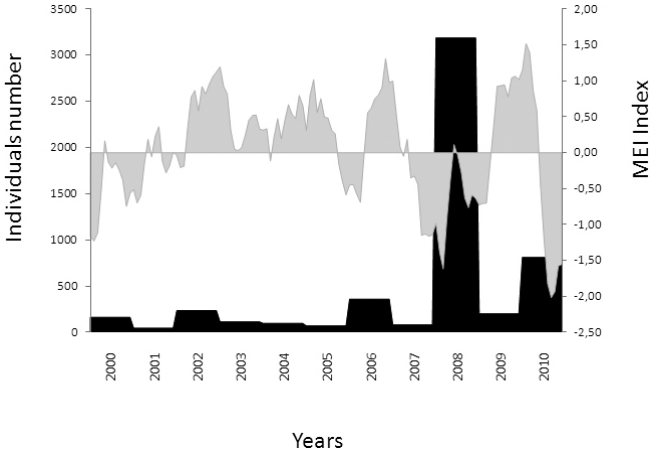

Fig. 2. The number of Magellanic Penguins arriving on the Brazilian coast per year (black) in relation to the MEI (gray), 2000 to 2010.

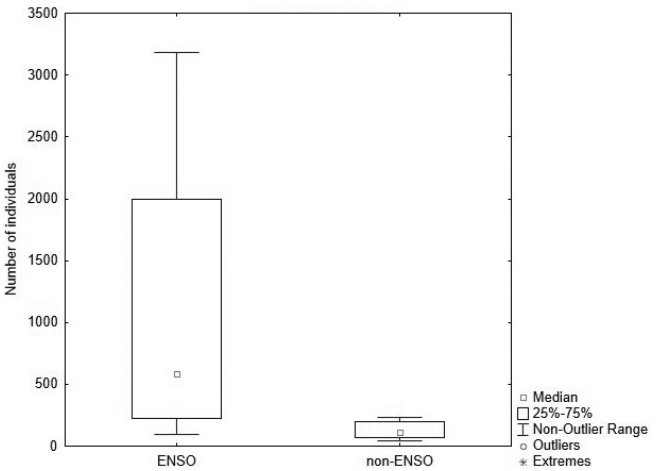

Fig. 3. Box-plot comparing the number of Magellanic Penguin individuals that arrived on the Brazilian coast during ENSO and non-ENSO years.

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