



## Magellanic penguin mortality in 2008 along the SW Atlantic coast

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### ABSTRACT

Magellanic penguins migrate from Patagonia reaching northern Argentina, Uruguay, and southern Brazil on their winter migration, in parallel with the seasonal pulse of anchovy spawning. In 2008, Magellanic penguins went further north than usual. Many died and a few swam nearly to the Equator. Twelve groups surveyed 5000 km of coastline encountering 3371 penguins along the coast. Most penguins arrived in northern Brazil (68.4%) without petroleum (2933, 87%). Almost all penguins without petroleum were juveniles (2915, 99%) and 55% were alive when found. Penguins were dehydrated, anemic, hypothermic, and emaciated. Of the penguins with petroleum, 13% arrived in the southern half of Brazil, showing that petroleum pollution remains a problem along the SW Atlantic coast. The mortality occurred in the winter of 2008 when sea surface temperature were unusually cold perhaps reducing the prey for penguins.

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### 1. Introduction

The Atlantic breeding population of Magellanic penguins (*Spheniscus magellanicus*) reproduce along the coasts of Patagonia, from Complejo Islole Lobos (41°25'S, 65°2'W) south to the Beagle Channel (54°54'S, 67°23'W). They migrate from Patagonian colonies and reach northern Argentina, Uruguay, and southern Brazil on their winter migration from March to September, but rarely do they get as far north as Rio de Janeiro (21°S) (Boersma et al., 1990). Magellanic penguins swim thousands of kilometers every year in parallel with the seasonal pulse of anchovy spawning activity (Sanchez and Ciechowski, 1995; Pütz et al., 2000; Stokes et al., 1998). In most years, a few dozen to several hundred dead and live penguins are found, most of them oiled, and only a few are found farther north than Rio (García Borboroglu et al., 2006).

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The South-West Atlantic anchovy (*Engraulis anchoita*) range from the south of Brazil (24°) south to Patagonia (48°), inhabiting shallow water along the coast up to the deep water of the continental slope (Revina and Baranov, 1973). Anchovy follow the pulse of the seasons moving south in the summer and north in the winter. The distribution and abundance of South-West Atlantic anchovy spawners in this area is closely related to oceanographic processes (Lima and Castello, 1995).

During the autumn and winter migration of Magellanic penguins in 2008, penguins went farther north than usual and many died. Penguins reached northern Brazil and we document the location, number, and condition of the penguins that were admitted to 12 rehabilitation centers along the coast of Brazil.

### 2. Methods

We searched for organizations that counted, collected or received penguins during 2008 from southern Brazil, Santa Catarina

State (33°47'S, 53°21'W) to Ceará State (2°52'S, 41°16'W), northern Brazil, covering approximately 5000 km of coastline (Fig. 1). We contacted non-governmental organizations (NGOs), governmental agencies, research institutions, museums, rehabilitation centers, aquariums, and zoos. We used a directory that García Borboroglu et al. (2006) compiled in 2004, including all organizations that received and or counted penguins along the coast from Central America to Cape Horn. We asked all institutions to report the number of animals they found and rehabilitated, to monitor the impact of petroleum pollution along the SW Atlantic.

Twelve centers (Table 1) had data on how many live or dead penguins they found and their age classes (juveniles or adults). Some of them provided data on the penguin's body condition (weight, body temperature, and general condition), however, sample sizes varied as variables were not always measured. We provided centers with standardized forms to record location, and whether the penguin had petroleum or was petroleum free. People used ATV's or walked the coast. Coastal sectors were surveyed several times, particularly from May to September during penguin migration. When a dead penguin was found on the beach it was removed so it would not be counted on a subsequent visit. Centers received penguins from areas not necessarily near them so coverage includes much of the coast of Brazil. We used information published in newspapers and from fishers. Four institutions (Instituto Mamíferos Aquáticos, Aquário do Guarujá, R3 Animal and Centro de Recuperação de Animais Marinhos (CRAM)) had records from 1998 to 2008.

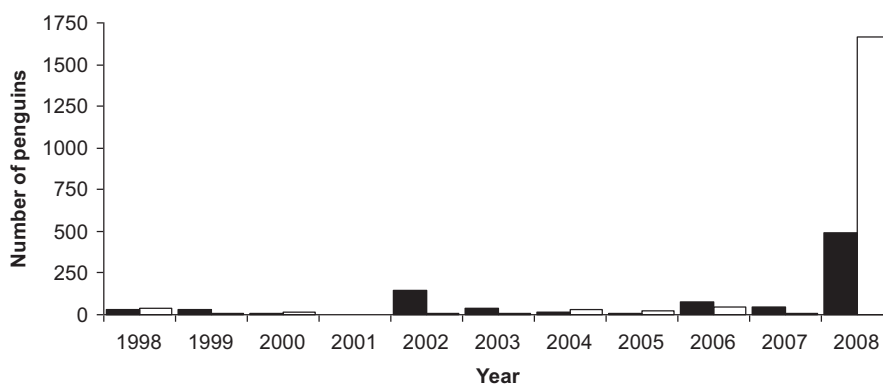
Boersma and colleagues banded 1000 Magellanic penguin fledglings in 2006, 2007, and 2008 at the Punta Tombo colony, Argentina (see Boersma, 2008). We report the number of these banded penguins found dead in Brazil in the winters of 2006–2008.

We examined patterns of anchovy availability and ocean surface temperature anomalies for the area of interest within the South-West Atlantic Ocean, using data available from NASA Ocean Motion (<http://oceanmotion.org/html/resources/ssedv.htm>) and Secretaría de Agricultura, Ganadería, Pesca y Alimentos (Argentina) (<http://medioambiente.gov.ar/?idarticulo=3856>) web sites. Mean sea surface temperature anomaly (SST) data came from three areas where penguins concentrate during their winter migration: 50°W–45°W, 30°S–25°S; 50°W–45°W, 35°S–30°S; and 55°W–50°W, 35°S–30°S. For each one of these areas, we defined the SST anomaly for each area as the deviation in temperature from the long-term average from 1981 to 2008. We compiled and analyzed the existing and available information of anchovy landings from March until June from 1991 to 2008, the stock of anchovy the penguins feed upon in the winter.

**Table 1**

Organizations that received penguins and/or survey beaches along the Brazilian coast during the 2008 mortality event.

| #  | Organization  | Location City, State          | Activities        |              | S      | W      |
|----|---|-------------------------------|-------------------|--------------|--------|--------|
|    |   |                               | Received penguins | Beach survey |        |        |
| 1  | Aquário de Natal  | Natal, Rio Grande Do Norte    | ●                 |              | 5°46'  | 35°11' |
| 2  | Instituto Mamíferos Aquáticos (IMA)   | Salvador, Bahia               | ●                 |              | 12°58' | 38°29' |
| 3  | Instituto Orca  | Vila Velha, Espírito Santo    | ●                 | ●            | 20°19' | 40°21' |
| 4  | Fundação RioZoo.  | Rio de Janeiro, Rio Janeiro   | ●                 |              | 22°27' | 42°43' |
| 5  | Animalia  | Ubatuba, Sao Paulo            | ●                 | ●            | 23°44' | 45°04' |
| 6  | Aquamundo   | Guarujá, Sao Paulo            | ●                 |              | 23°55' | 46°13' |
| 7  | CETAS UNIMONTE  | Santos, Sao Paulo             | ●                 | ●            |        | 45°04' |
| 8  | Aquário Municipal de Santos.  | Santos, Sao Paulo             | ●                 |              | 23°56' | 46°20' |
| 9  | GREMAR (Resgate y rehabilitacao de animais marinhos)  | Baixada Santista, Santos      | ●                 | ●            | 24°00' | 46°19' |
| 10 | IBAMA SUPES (Brazilian Institute of Environment and Natural Resources)  | Sao Paulo, Sao Paulo          | ●                 | ●            | 24°41' | 47°28' |
| 11 | R3 animal   | Florianópolis, Santa Catarina | ●                 | ●            | 27°35' | 48°34' |
| 12 | Centro de Recuperação de Animais Marinhos (CRAM), Museu Oceanográfico Prof. Eliézer de C. Rios, Fund. Univ. Federal do Rio Grande | Rio Grande, Rio Grande do Sul | ●                 |              | 32°03' | 52°08' |



**Fig. 1.** Penguins with petroleum (solid black bars) and without petroleum (empty bars) found along the Brazilian coast from 1998 to 2008. Four organizations surveyed the coast from 1998 to 2008 (Instituto Mamíferos Aquáticos, Aquário do Guarujá, R3 Animal and Centro de Recuperação de Animais Marinhos (CRAM)).

### 3. Results

#### 3.1. Penguins

Thousands of Magellanic penguins ( $n = 3371$ ) washed ashore on the coasts of Brazil from southern Brazil ( $33^{\circ}47'S$ ,  $53^{\circ}21'W$ ) to northern Brazil ( $2^{\circ}52'S$ ,  $41^{\circ}16'W$ ) in the southern hemisphere winter and spring (June to November) of 2008. Penguins came ashore along approximately 5000 km of coastline. One penguin was found 350 km south of the Equator, swimming at least 6000 km from the nearest breeding colony in Patagonia and surpassing the previous northernmost record for this species (García Borboroglu et al., 2006). The number of penguins found along the Brazilian coast during the 2008 winter was several orders of magnitude higher than the ones found since 1998 by four major organizations (Fig. 1). During the winter months of 2008, six banded penguins were found dead in Brazil, compared to only two in 2007 and two in 2009.

Penguins started to wash ashore on beaches in southern Brazil on June 16, 2008 and appeared on beaches in northern Brazil by July 30. The last penguin was found ashore on November 20

2008. In late July and early August 2008 the rehabilitation centers admitted the most penguins. In August in the north, the daily average of penguins brought to the centers reached 80 penguins/day.

Juveniles were the vast majority of penguins (97%) found. Only 112 adults were found (3%,  $n = 3371$ ). Slightly more than half of the penguins (63%,  $n = 2114$ ) were found alive, but 98 of these penguins died shortly after they were captured (5%). The rest of the penguins (37%,  $n = 1257$ ) were found dead.

Out of the 3371 penguins found, 438 (13%) were oiled. Most oiled penguins were juveniles (78.5%, 344 penguins) but 94 (21.5%) were adults. When penguins were oiled and alive, 93% improved during rehabilitation and were released ( $n = 408$ ). Penguins with petroleum were found only in the southern half of the Brazilian coast (Fig. 2). Penguins with petroleum (78%,  $n = 340$ ) mostly came ashore in Santa Catarina State ( $29^{\circ}18'38''S$ ,  $49^{\circ}42'8''W$ – $26^{\circ}0'10''S$ ,  $48^{\circ}34'17''W$ ), but 18% ( $n = 78$ ) appeared in Rio Grande do Sul State ( $33^{\circ}44'29''S$ ,  $53^{\circ}23'36''S$ – $29^{\circ}18'38''S$ ,  $49^{\circ}42'8''W$ ), 2%, ( $n = 10$ ) in Sao Paulo State ( $25^{\circ}14'42''S$ ,  $47^{\circ}59'52''W$ – $23^{\circ}23'14''S$ ,  $44^{\circ}44'21''W$ ) and another 2% ( $n = 10$ ) in Espírito Santo State ( $21^{\circ}16'54''S$ ,  $40^{\circ}56'7''W$ – $18^{\circ}21'27''S$ ,  $39^{\circ}39'15''W$ ). We found no clear relationship between when a penguin with petroleum

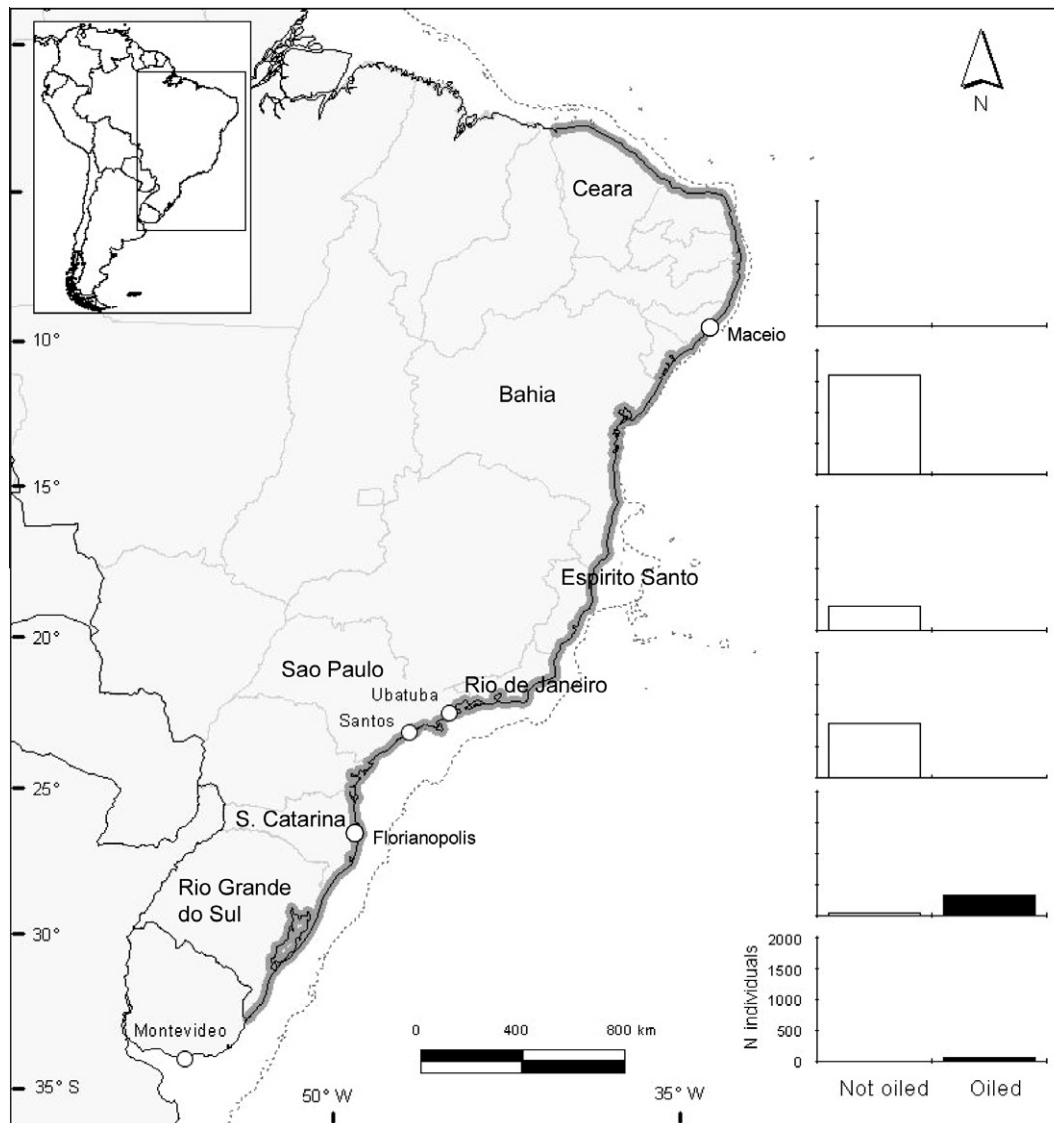


Fig. 2. The coast of Brazil showing six sectors where penguins were found. Bars show the number of penguins without petroleum (empty bars) and penguins with petroleum (black bars).

arrived and latitude. In Ubatuba (23°22'S, 44°53'W), Sao Paulo State, one penguin appeared on July 23rd and two others were found on September 4th and 5th, near Santos (24°S, 46°26'W) seven more arrived in late June and early July and 340 came ashore farther south between August 24th and September 29th at Florianopolis (27°30'S, 27°30'W). Most of the 78 penguins found in Rio Grande (33.5°S) appeared in June (after the Syros oil spill in Montevideo).

Most penguins that came ashore (87%, 2933) were without petroleum. 68.4% ( $n = 2004$ ) went to rehabilitation centers located in northern Brazil (Fig. 2). Penguins without petroleum came ashore mainly along four consecutive States: Bahia, Espirito Santo, Rio de Janeiro, and Sao Paulo, where 7 of the 12 centers are located. There was a clear relationship between when a penguin arrived and latitude. Penguins without petroleum arrived in southern Brazil by 20 June, in Central Brazil around 10 July and last in Northern Brazil by July 30.

Almost all of the penguins without petroleum were juveniles ( $n = 2933$ ) but 18 were adults (<1%). Most penguins were found alive (55%,  $n = 1608$ ) but 42% were dead ( $n = 1228$ ), and the rest 3% ( $n = 97$ ) died during rehabilitation.

Ninety-eight percent of the penguins received by one of the centers (Animalia) were dehydrated and anemic ( $n = 106$ ), the condition of the majority of the animals received, although not quantified at all the centers. Thirteen percent of the penguins had white plaques in their mouths, indicating *Candida* sp. infection and immune suppression ( $n = 441$ ). Out of the 77 penguins received by Acquamundo, 43% were hypothermic with a body temperature between 32.6 and 37.8 °C (normal avian body temperature = 39 °C),

while 3% of the penguins that were alive had aspergillosis ( $n = 75$ ). Parasites (mostly round worms) were in the stomach and intestines of 72% of dead penguins necropsied ( $n = 784$ ).

Penguins without petroleum that came ashore were weak and emaciated. Normal weight is between 3 and 5 kg (Boersma et al., 1990; Williams and Boersma, 1995). Almost 70% weighed less than 3 kg, with a minimum weight of 1.03 kg ( $2.39 \pm 0.48$  kg,  $n = 523$ ). The rest of penguins weighed more ( $3.43 \pm 0.26$  kg,  $n = 241$ ). The weight of penguins coming ashore during June and July varied (Fig. 3). All the penguins with petroleum that were weighed, were skinny weighing  $1.92 \pm 0.19$  kg,  $n = 9$ .

### 3.2. Anchovies

The total anchovy landings from March until June between 1992 and 2008 showed that 2008 was 1 of 5 years with low catches (Fig. 4). Like 2008, catches of anchovy were low in 2007 and 2006. Landing in 1999, 2000, and 2002 likely reflects the long strike in Argentina in those years and not anchovy abundance.

### 3.3. Sea surface temperature (SST) anomaly

In spring 2007, the surface waters were anomalously cold in the area when 80% of the anchovy spawned (Fig. 5a–c). The average anomaly for that year ( $-0.84 \pm 0.29$  °C,  $n = 12$ ) was significantly lower than the average for all the past 26 years ( $-1.82 \pm 0.99$  °C,  $n = 221$ ) ( $t = 6.3$ ,  $P < 0.001$ ). Moreover, the anomaly lasted 3 months, which is the longest anomaly since 1981, when data are available.

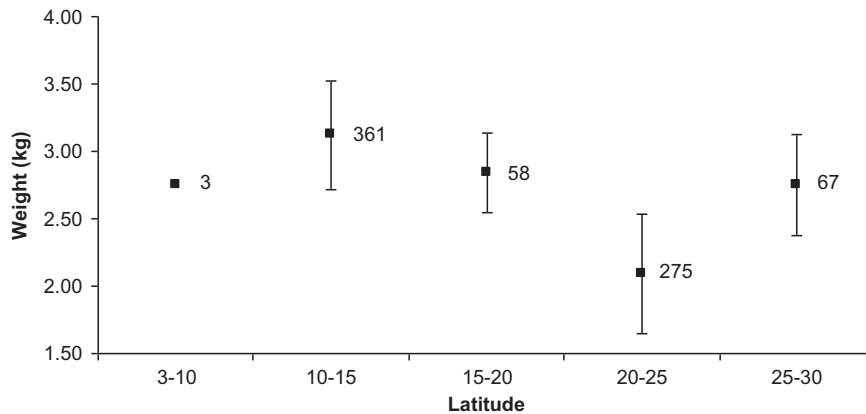


Fig. 3. Weight of penguins by the latitude range where it was found along the coast of Brazil is shown by a solid square. The SD and samples sizes are shown.

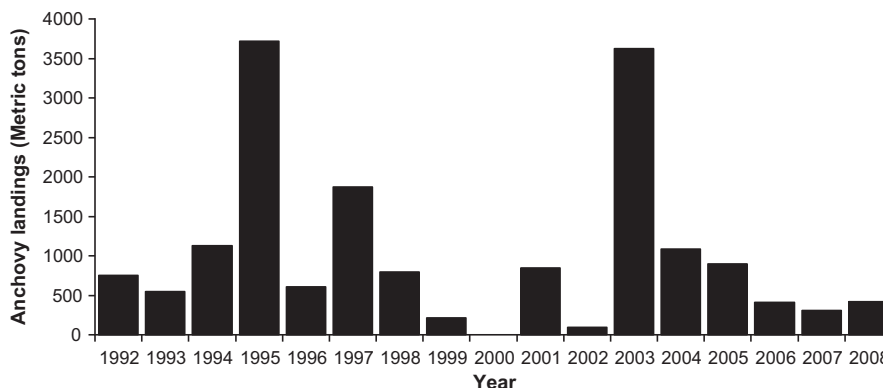


Fig. 4. Anchovy landings from 1992 to 2008 (March until June) in metric tons. Source: Secretaría de Agricultura, ganadería, pesca y alimentos, Argentina. (<http://www.sagpya.mecon.gov.ar/>).



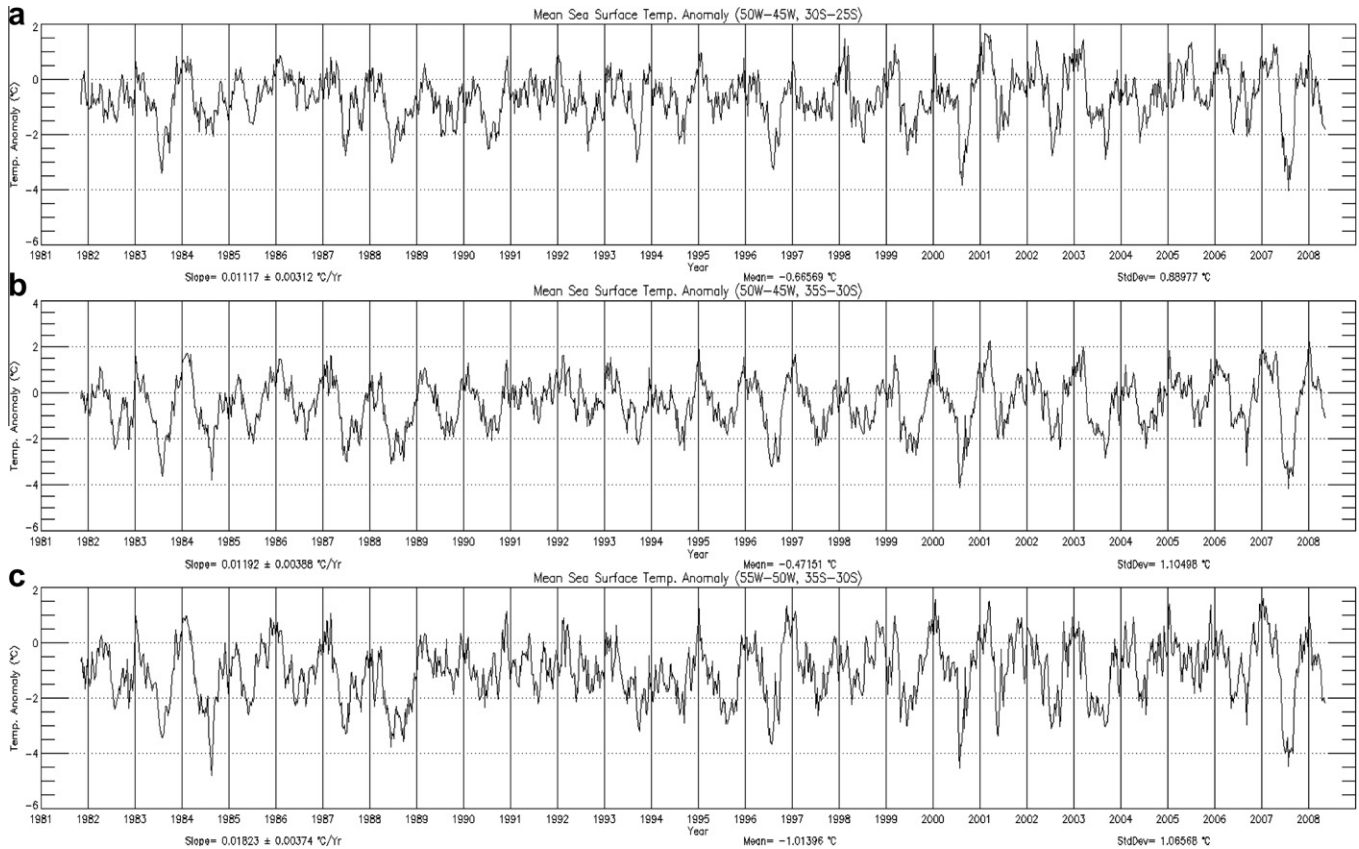


Fig. 5. (a–c) Mean sea surface temperature anomaly for three sectors of the Brazilian Continental shelf. (a) 50°W–45°W, 30°S–25°S; (b) 50°W–45°W–35°S–30°S; (c) 55°W–50°W–35°S–30°S. Source: NASA (<http://oceanmotion.org/html/resources/ssedv.htm>).

#### 4. Discussion

We found that in 2008 Magellanic penguins went much north than normal with some found near the Equator (2°52'S). Normally, penguins are found in the southern coasts of Brazil and few as far north as Rio de Janeiro (Boersma et al., 1990) while the previous northernmost record corresponded to the city of Maceio (9°37'S, 35°44'W) (García Borboroglu et al., 2006). Three times as many banded penguins were found dead in Brazil in 2008 compared to 2007 and 2009, consistent with observations that penguins were going farther north and many died. Usually, Magellanic penguins stay along the Atlantic coasts of northern Argentina, Uruguay, and southern Brazil with their abundance declining at lower latitudes (Boersma et al., 1990). In 2008, most penguins appeared in the northern half of coastal Brazil with more penguins found from 20°S northwards.

Historically, petroleum pollution was the most common reason penguins died along the coasts (Gandini et al., 1994; García Borboroglu et al., 2006; Boersma, 2008). Commonly, 77% of penguins found are oiled (García Borboroglu et al., 2006). In 2008, only 13% of the penguins had petroleum. Even though the percentage of penguins that had petroleum was small, almost 500 birds encountered petroleum, confirming that chronic oil pollution is a major problem in the SW Atlantic. Petroleum pollution in their wintering area is likely an important mortality factor for Magellanic penguins.

The lack of a spatial and chronological pattern in the stranding of penguins with petroleum suggests that petroleum pollution is not restricted to one place and that even when covered in petroleum, a penguin can swim a long way before it comes ashore. Foraging penguins can swim 170 km in a day (Boersma et al., 2009).

The 78 penguins found in the Brazilian border may have encountered petroleum from the Syros oil spill, where after two ships collided on June 3 2008 a 20 km slick of bunker fuel appeared off Montevideo, Uruguay. Because of their stored fat and ability to fast several weeks, a penguin could travel hundreds of kilometers away from where it was oiled which is likely why there was no clear pattern between penguins with petroleum and latitude.

Most penguins found along the coasts were not oiled and many were skinny. The low body weight and poor condition of penguins found ashore suggests that lack of food is probably what killed penguins in 2008. Penguins may have migrated farther north than normal seeking food. Two thirds of the penguins that washed ashore in the northern half of Brazil without petroleum were juveniles and half of them were dead or died during treatment. These penguins were dehydrated, anemic, hypothermic, and emaciated. There was a clear chronological and geographical pattern in the penguins' strandings, with the first animals arriving in southern Brazil in late June and in northern Brazil by late July again suggesting that the birds continued to move north searching for food. Most of the penguins were starving and the majority were young fledglings. Interestingly some of the penguins probably found food as they moved north as their average body weight increased. Nonetheless, fish abundance was apparently not adequate to sustain them.

Most chicks fledge during February and early March, migrating northward from their colonies in Patagonia (Boersma et al., 1990) together with the anchovy stock movement. There are two anchovy stocks, the Bonaerense (north) and the Patagonico (south) (Brandhorst et al., 1974; Hansen et al., 1984). During the winter, the Bonaerense stock adults gather in the northern maritime area of Argentina, Uruguay, and southern Brazil and are the richest prey

of the area. In the spring and early summer, the reproductive activity of the anchovy northern stock spreads south (Sanchez and Ciechowski, 1995; Lima and Castello, 1995). Between December and May anchovy leave shallower waters and are found in the intermediate and exterior areas of the continental shelf. By the end of autumn, anchovies are further from the coast, reaching the waters over the external part of the continental shelf and slope, between 33° and 37°, where they remain during the winter.

When penguins arrived at the wintering areas in southern Brazil in 2008 they likely found few anchovy as the anchovy population estimates suggest anchovy numbers were low. Variable oceanographic conditions can influence both prey density and seabird foraging (Ainley and Boekelheide, 1990; Robinson et al., 2005; Congdon et al., 2007; Montevecchi and Myers, 1996). Anchovy abundance is related to both the sea surface temperature, salinity, and the stratification of the water column (Hansen et al., 2001). In the years when anchovy was particularly abundant, the region showed wide saline front zones, and relatively high temperatures (Martos et al., 2005). In addition, anchovy larvae produced in spring and summer are retained in northern Argentina depending on the influx of warm waters on the continental shelf, while other anchovy are driven to lower latitudes by the higher intensity sub Antarctic water and the flux of water from the Rio de la Plata along the southern coast of Brazil (Martos et al., 2005). The SST anomaly was more intense in late 2007 and lasted longer according to historical records and occurred during the 2007 anchovy spawning season. The cold waters likely reduced anchovy larvae survival for the following year when penguin fledglings left their colonies.

Fledgling penguins that continued migrating north probably encountered other local fish species such as sardines (*Sardinella brasiliensis*). If they did, their average weight should increase which is what we found for penguins reaching lower latitudes. Nonetheless, body weights show these penguins were in poor condition.

Interestingly, most penguins came ashore in coastal sectors where the continental shelf is narrow and the slope is close to the mainland. In winter, anchovies stay on the external part of the continental shelf and slope (Martos et al., 2005), where penguins might normally spend the winter. Although lots of penguins were found dead in 2008 they likely represent a small fraction of the affected penguins along the coast. It is not surprising that most penguins came ashore near the continent where the shelf is narrow because it is an easy place for them to land and fish should be present. In most coastal sectors the continental shelf is wider so penguins likely would be farther from the coast when hunting. Fishers saw large groups of dead penguins floating far from the coast. Our data underestimates the number of dead penguins because most of the penguins that died at sea far from the coast likely were never washed ashore. Nonetheless, band recoveries suggest that three times the numbers of penguins died in 2008 compared to 2007 or 2009.

In 2008 penguins migrated farther north than usual, had trouble finding food, and many starved. Mostly juveniles died of starvation farther north than where they would normally occur. Probably fewer adults died because adults, particularly breeding ones, do not move as far north as fledglings.

Oil pollution remains a chronic problem killing penguins each year (Boersma, 2008). Mostly, petroleum chronic pollution is a problem from northern Argentina to southern Brazil where petroleum development and maritime traffic are intense (García Borboroglu et al., 2006).

Reduced prey could have been caused by anomalous ocean conditions found during the winter migration, potentially linked to climate variability. Increased variability is one of the predictions of climate warming (IPCC, 2007) and is likely a new source of mortal-

ity for Magellanic penguins. Magellanic penguins are sentinels of ocean conditions and reflected the anomalous ocean conditions of 2008 from Brazil to northern Argentina.

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