

# Winter migration of magellanic penguins (*Spheniscus magellanicus*) from the southernmost distributional range

Klemens Pütz · Adrian Schiavini · Andrea Raya Rey · Benno H. Lüthi

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**Abstract** A total of 22 magellanic penguins (*Spheniscus magellanicus*) from Isla Martillo in the Beagle Channel, Argentina, were successfully satellite tracked in 2004 ( $n = 7$ ), 2005 ( $n = 7$ ) and 2006 ( $n = 8$ ) to monitor their winter migration after moult. Only one magellanic penguin migrated northwards into the Pacific Ocean, whereas all others remained in the Atlantic Ocean. In general, these birds left the island in an easterly direction, rounded Cabo San Diego, the southeasterly tip of South America, and continued northwards occupying inshore waters mostly less than 50 km from the coast, only occasionally venturing further offshore. By the end of the transmission period, birds were still travelling northwards and the most northerly

positions were obtained from birds located in the area of Peninsula Valdés, Argentina, at a latitude of around 42°S, some 1,500 km from their breeding site on Isla Martillo. The mean maximum distance to the breeding site was, however, only  $624 \pm 460$  km. The mean minimum distance covered during the study period was  $1,440 \pm 685$  km, which corresponded to a mean distance of  $23.2 \pm 6.6$  km covered per day. The northbound migration of the penguins could be separated into periods of rapid movement, interspersed with periods during which the birds remained for some time in particular coastal regions. Areas with a high density of daily penguin positions were observed in three distinct areas: at the northeastern coast of Tierra del Fuego, at the southern entrance of Golfo San Jorge and to the northeast of the Peninsula Valdez. The observed migration pattern is presumably driven by the formation and subsequent dispersal of areas of enhanced productivity as the season progressed. Our findings also suggest that magellanic penguins are increasingly threatened by human activities in coastal areas as penguins migrate northwards.

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K. Pütz  
Antarctic Research Trust, PO Box 685,  
Stanley FIQQ 1ZZ, Falkland Islands

A. Schiavini · A. R. Rey  
Consejo Nacional de Investigaciones Científicas y Técnicas,  
CADIC, Bernardo Houssay 200, (V9410BFD) Ushuaia,  
Tierra del Fuego, Argentina

A. Schiavini  
Wildlife Conservation Society, 2300, Southern Blvd,  
Bronx, NY 10460, USA

B. H. Lüthi  
Antarctic Research Trust (Switzerland),  
General-Guisanstr. 5, 8127 Forch, Switzerland

K. Pütz (✉)  
Am Oste-Hamme-Kanal 10, 27432 Bremervörde, Germany  
e-mail: puetz@antarctic-research.de

## Introduction

The successful conservation of apex marine predators requires detailed knowledge about their temporal and spatial distribution, migration patterns and habitat utilisation, in particular how these elements are impacted by environmental forcing, including human activities. For land-based marine predators, foraging ranges are usually restricted during the breeding season because of their need to provision offspring. During these periods, aspects of environmental impact have been well studied and many published reports exist in the literature. However, after the breeding season, many species need to migrate to other latitudes in order to

find adequate food resources or to avoid adverse environmental conditions, particularly those species breeding at higher latitudes (e.g., Schreiber 2001). Range information at these times is difficult to obtain. Thus, knowledge about the winter distribution of many species and their potential conflicts with anthropogenic factors, remain poorly understood.

The Patagonian Shelf is utilized by a wide variety of upper-trophic level marine predators, including cetaceans, pinnipeds and seabirds. Many of these species spend most of their life at sea, as a consequence, knowledge concerning their distribution is limited. Nevertheless, human exploitation of regions used by many of these species indicates increasing threats to their survival. One of the most numerous marine top predators in the area is the magellanic penguin (*Spheniscus magellanicus*). The breeding distribution of this species is restricted to coastal locations between Cape Horn and 42°S, as well as sites on the Falkland Islands/Malvinas. The total world population is estimated to comprise more than 1 million breeding pairs along the continental coast with an additional 100,000 breeding pairs on the Falkland Islands/Malvinas (Williams 1995; Woods and Woods 1997). Over the past 100 years, the population has fluctuated significantly: from the early twentieth century until the 1980s numbers increased, but over the latter part of the twentieth century, numbers decreased, at least at many breeding sites (Boersma et al. 1990; Williams 1995).

Many aspects of the biology and ecology of magellanic penguins have been investigated in the past, including their breeding biology (Boersma et al. 1990; Pütz et al. 2001; Clausen and Pütz 2002; Otley et al. 2004), diet (Thompson 1993; Scolaro et al. 1999; Fonseca et al. 2001; Pütz et al. 2001; Clausen and Pütz 2002; Forero et al. 2002), diving behaviour (Peters et al. 1998; Radl and Culik 1999; Simeone and Wilson 2003; Walker and Boersma 2003; Wilson et al. 2005), foraging behaviour (Wilson et al. 1995; Stokes et al. 1998; Stokes and Boersma 1999; Pütz et al. 2000, 2002a; Boersma et al. 2002), and behavioural changes consequent on human disturbance (Walker et al. 2005, 2006). Annual variability in breeding success was shown to be predominantly related to changes in the quantity and quality of diet, particularly towards the onset of the breeding season, or to weather conditions (Boersma et al. 1990; Williams 1995). However, population trajectories are also related to mortality throughout the year, which may be impacted by a number of human-related factors, including commercial fishing (Gandini et al. 1999; Pütz et al. 2001), oil pollution (Perkins 1983; Gandini et al. 1994; Borboroglu et al. 2006) and disturbance due to tourism (Walker et al. 2006).

One of the largest colonies of magellanic penguins is located at Punta Tombo, Argentina. Towards the end of winter, animals from this colony as well as conspecifics

originating from the Falkland Islands/Malvinas migrate northwards during winter, in some instances as far as 13°S to southern Brazil (Williams 1995; Stokes et al. 1998; Pütz et al. 2000). However, the post-breeding migratory behaviour of penguins from the southern range, is as yet unknown. The breeding colony on Isla Martillo in the Beagle Channel, Argentina, is located at the boundary between the Atlantic and Pacific Oceans and is one of the southernmost colonies. Consequently, the aim of this study was to investigate the winter migration of magellanic penguins originating from the southern range of their breeding distribution in order to identify their distribution after the breeding season and to identify potential conflicts with human activities. The study was carried out over a period of 3 years in order to allow for inter-annual variability.

## Materials and methods

Fieldwork was conducted at the magellanic penguin breeding colony located on Isla Martillo (54°54.5'S, 67°22.5'W) in the Beagle Channel, Argentina. The island is located half way between the town of Ushuaia and the eastern entrance of the Beagle Channel. The magellanic penguin colony on Isla Martillo comprised about 2,000 breeding pairs (Schiaivini, unpublished data).

Overall, 22 adult magellanic penguins (12 males and 10 females) were randomly selected and equipped with satellite transmitters on 23 March 2004 ( $n = 7$ ), 22 March 2005 ( $n = 7$ ) and 17 March 2006 ( $n = 8$ ) after completion of their moult. After their capture, penguins were weighed (mean weight females:  $3.3 \pm 0.4$  kg; mean weight males:  $3.9 \pm 0.4$  kg) and bill dimensions measured (mean bill depth and length females  $21.3 \pm 0.7$  mm and  $53.1 \pm 2.1$  mm; mean bill depth and length males:  $25.8 \pm 1.8$  mm and  $59.6 \pm 1.9$  mm) to determine their gender (*sensu* Scolaro et al. 1983). Statistical comparison (Mann–Whitney  $U$ -test) of morphometric data revealed significant differences ( $P < 0.05$ ) between the sexes with regard to weight ( $U = 27$ ) and bill dimensions ( $U = 30$ ). The satellite transmitters were attached on the mid-line of the back using black tape (Tesa, Beiersdorf AG, Hamburg, Germany) and 2-component neoprene glue (Deutsche Schlauchbootfabrik, Eschershausen, Germany) according to the method described by Wilson et al. (1997). In order to minimise the hydrodynamic drag (Bannasch 1995), in 2004 devices were attached as far distally as possible without impairing the preen gland, whereas in 2005 and 2006 devices were attached to the middle back in order not to compromise the penguins' balance (Chiaradia et al. 2005). The devices were then covered with a layer of quick epoxy (Loctite® 3430, Loctite Deutschland GmbH, München, Germany) to prevent the birds from removing

the tape with their beaks. The whole process took less than 20 min per bird.

The KiwiSat 101 satellite transmitters (Sirtrack, Havelock North, New Zealand) had maximum dimensions of  $130 \times 35 \times 20$  mm and were hydrodynamically-shaped following the recommendations by Bannasch et al. (1994). The satellite transmitters were powered by 2 AA lithium cells and weighed approximately 100 g, equivalent to about 2.7% of the mean penguin body mass of  $3.7 \pm 0.5$  kg. In order to further reduce hydrodynamic drag (Wilson et al. 2004), the flexible antenna, 170 mm long and 3 mm in diameter, protruded at an angle of  $60^\circ$  from the rear of the device. In 2006, apart from five KiwiSat 101, three KiwiSat 202 were attached to the penguins (Birds *NN1*, *NN2* and *NN3*). These transmitters had maximum dimensions of  $60 \times 35 \times 20$  mm and weighed approximately 60 g, equivalent to about 2% of the mean penguin body mass of  $3.0 \pm 0.4$  kg. At least three (2004) and five (2005) of the study birds equipped with satellite transmitters were re-sighted during the following breeding period, identified by the lack of feather tips in an area on their back corresponding to the basal shape of the transmitters.

To reduce the energy requirements of the satellite transmitters, devices were programmed to transmit with a duty cycle of 6 h on/18 h off with a repetition period of 60 s, and were equipped with a saltwater switch that prevented transmission while under water. All transmitters were switched on at 22:00 local time (=GMT -3 h), because penguins are optically orientated predators and thus more likely to be less active at night (Wilson et al. 1993), thereby increasing the likelihood of successful transmissions while the penguin was resting at the surface. The mean number of locations received per duty cycle was  $9.5 \pm 2.8$  (range 5.9–13.9). Positional data obtained from Argos (CLS, Toulouse, France) were classified according to the quality of the positional fix, with location classes 0, 1, 2 and 3 representing accuracies of  $>1$  km,  $<1$  km,  $<350$  m and  $<150$  m, respectively (Argos 1996). Only the most accurate position obtained in each duty cycle for each penguin was processed as “daily position” (98%, of which were accurate to within 1 km or better). All daily positions were transferred to MAPINFO Professional 5.0 (MapInfo Corporation, Troy, NY, USA) for graphical display of the migration routes and the creation of a density distribution map based on a resolution of  $0.5^\circ$  longitude  $\times$   $0.5^\circ$  latitude by using the integrated raster grid procedure.

In the KiwiSat 101, a surface time counter (STC) also continuously recorded and subsequently transmitted the time birds spent at the surface. The STC could record a maximum of 43,200 units (1 unit = 2 s), or 1 day. Surface time values were used to calculate time spent underwater

by subtracting the time spent at the surface from the time elapsed between two positional fixes.

Statistical comparisons between study years were performed using Kruskal-Wallis test and Dunn post hoc comparisons, whereas Mann-Whitney *U*-test was used to compare the two transmitter modifications used in 2006.

## Results

During the study period, and excluding positions located in the colony, a total of 1,340 daily positions were obtained from 22 migrating magellanic penguins (Table 1). Cessation of transmission occurred after a mean period of  $61 \pm 25$  days (range 13–103). However, transmission periods differed significantly between 2004 and the following 2 years (Table 2): in 2004 the mean transmission period was  $36 \pm 18$  days, whereas it was twice as long in 2005 ( $74 \pm 11$  days) and 2006 ( $71 \pm 23$  days). The minimum distance travelled and the maximum distance to the colony are both dependent to a certain extent on the transmission period. Consequently, large differences were observed in these parameters between the study years. The mean minimum distance travelled by all penguins was  $1,440 \pm 685$  km, the mean distance covered per day was  $23.2 \pm 6.6$  km (Table 1). The mean maximum distance to the colony was  $624 \pm 460$  km (Table 1). However, the only significant difference occurred between 2004 and 2005 with regard to the minimum distance travelled (Table 2). Comparable temporal differences with regard to time spent underwater were not noted, and penguins spent  $52.8 \pm 6.3\%$  of their time at sea submerged (Table 1). Sex-related differences were only found with regard to penguin body mass and beak dimensions (see “Materials and methods”), but not with regard to transmission duration and migratory parameters (Table 2). Also, no significant differences in migratory parameters were detected between the two transmitter modifications used in 2006 (Mann-Whitney *U*-test; transmission duration:  $U = 20$ ,  $P = 0.551$ ; maximum distance to the colony:  $U = 24$ ,  $P = 0.766$ ; minimum distance covered:  $U = 25$ ,  $P = 0.551$ ).

Eventually, all 22 satellite tracked magellanic penguins left the Beagle Channel in an easterly direction and, with only three exceptions (see below), travelled around Cabo San Diego, the southeasterly tip of South America, into the Atlantic (Fig. 1). Then, penguins headed north and migrated along the Argentine coast until transmission ceased. However, in two birds, *Fyjima* and *NN2*, transmission ceased before reaching Cabo San Diego. The third bird, *NN3*, headed west after exiting the Beagle Channel, rounded the southern tip of South America and then travelled along the Chilean Pacific coast northwards until transmission ceased (Fig. 1).

**Table 1** Summary of parameters characterising the migratory behaviour of magellanic penguins from Isla Martillo

Penguin	Sex	Start of migration	End of transmission	Duration(days)	Time under water (%)	Max. distance to colony (km)	Min. distance covered (km)	Distance covered per day (km/day)
Fyjima	F	26.03.04	08.04.04	13	54.9	96	136	10.5
Miriam	F	31.03.04	17.04.04	17	54.8	196	467	27.5
Lu	F	03.04.04	26.04.04	23	52.1	209	538	23.4
WaRu	M	30.03.04	14.05.04	45	50.7	157	757	16.8
Fips	F	29.03.04	15.05.04	47	51.1	1,246	1,701	36.2
Flo	M	28.03.04	16.05.04	49	49.9	349	823	16.8
Silvester	M	05.04.04	01.06.04	57	50.8	1,233	1,816	31.9
Jennifer	F	10.04.05	09.06.05	60	65.1	474	1,590	26.5
Eva	F	23.03.05	27.05.05	65	53.2	1,079	1,837	28.3
Jupp	M	01.04.05	08.06.05	68	52.2	682	1,635	24.0
Biggi	F	29.03.05	08.06.05	71	52.0	327	1,429	20.1
Schröder	M	29.03.05	19.06.05	82	58.2	899	2,628	32.0
The Boss	M	26.03.05	20.06.05	86	50.0	967	2,150	25.0
Egregrius	M	03.04.05	29.06.05	87	57.7	1,534	2,504	29.8
NN 2 <sup>a</sup>	M	19.03.06	15.04.06	27		71	402	14.9
Gimmy	M	20.03.06	17.05.06	58	42.9	173	1,470	25.3
Klaus	M	24.03.06	25.05.06	62	57.7	476	1,448	23.4
Whitney	F	23.03.06	03.06.06	72	50.6	530	1,420	19.7
Florian	M	18.03.06	04.06.06	78	37.4	325	1,367	17.5
Kira	F	18.03.06	08.06.06	82	62.7	1,189	2,122	25.9
NN 3 <sup>a</sup>	M	19.03.06	15.06.06	88		1,215	2,144	24.4
NN 1 <sup>a</sup>	F	18.03.06	29.06.06	103		294	1,294	12.6
Mean 2004				35.9 ± 17.7	52.0 ± 2.0	498 ± 512	891 ± 634	23.3 ± 9.2
Mean 2005				74.1 ± 10.8	55.5 ± 5.2	852 ± 404	1,968 ± 467	26.4 ± 3.8
Mean 2006				71.3 ± 22.9	50.3 ± 10.4	534 ± 438	1,458 ± 543	20.5 ± 5.1
Sum				1,340			31677	
Total mean				60.9 ± 24.6	52.8 ± 6.3	624 ± 460	1,440 ± 685	23.2 ± 6.6

The minimum distance covered is the sum of all distances between consecutive positions and does not take into account deviations from a straight line course

<sup>a</sup> Satellite transmitter modifications used did not allow calculation of time spent underwater (see “Materials and methods”)

**Table 2** Statistical comparison of transmission duration and migratory parameters of magellanic penguins from Isla Martillo using Mann-Whitney *U*-test between sexes and Kruskal-Wallis test and Dunn post hoc comparisons between study years

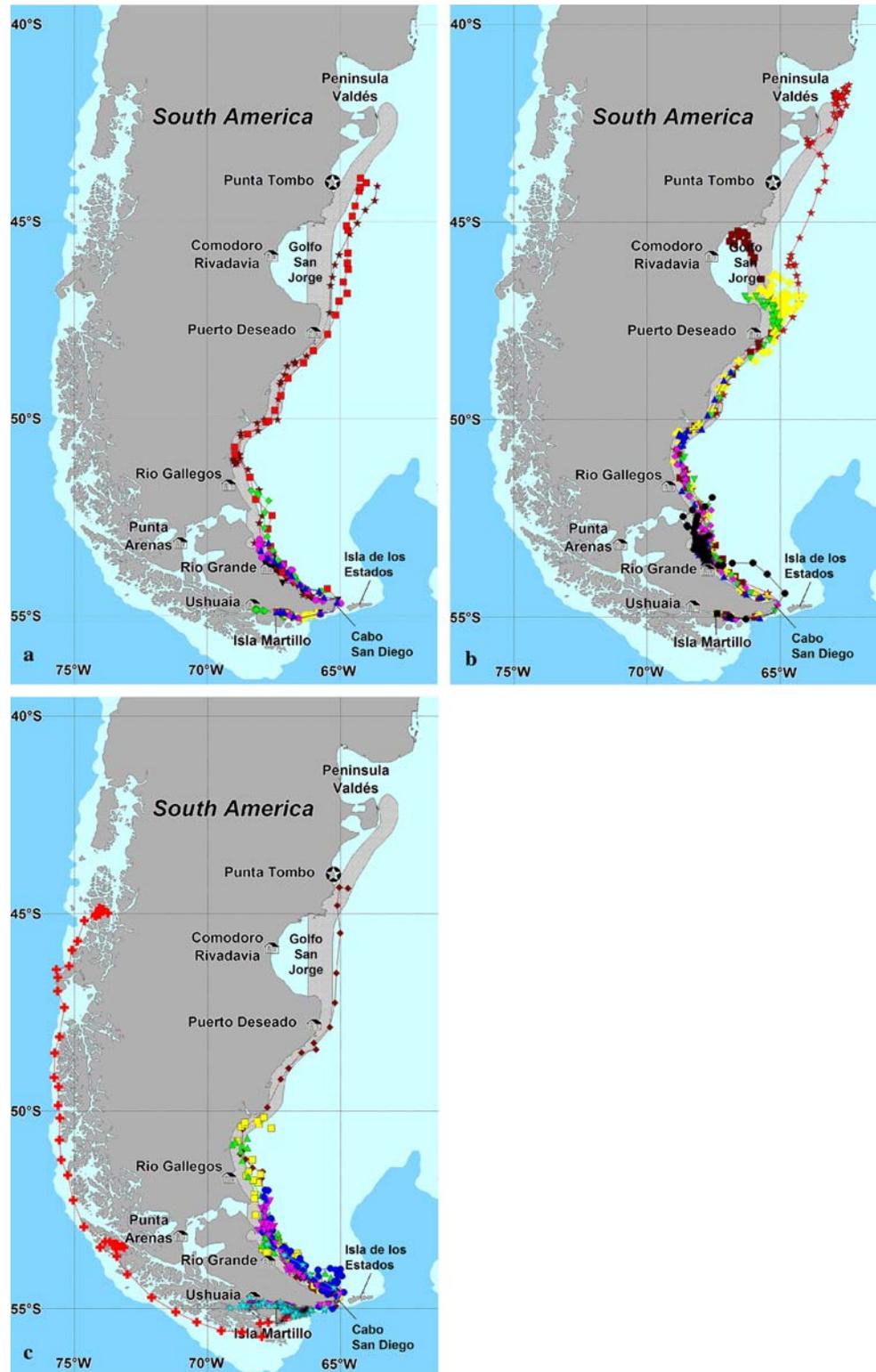
	Duration of Transmission		Time under water		Max. distance to colony		Min. distance covered	
Sex	U	P	U	P	U	P	U	P
	102.5	0.43	108	0.15	109	0.72	97	0.25
Year	H	P	H	P	H	P	H	P
	11.55	0.003	2.2	0.332	2.29	0.318	7.22	0.02

Significant inter-annual differences were noted with regard to transmission duration and minimum distance covered between 2004 and the other two study years. For details see text

The migratory behaviour of the magellanic penguins could be decomposed into periods of rapid movement in a northerly direction, interspersed with periods, during which the birds remained for some time in a certain area. Due to these individual migratory patterns and transmis-

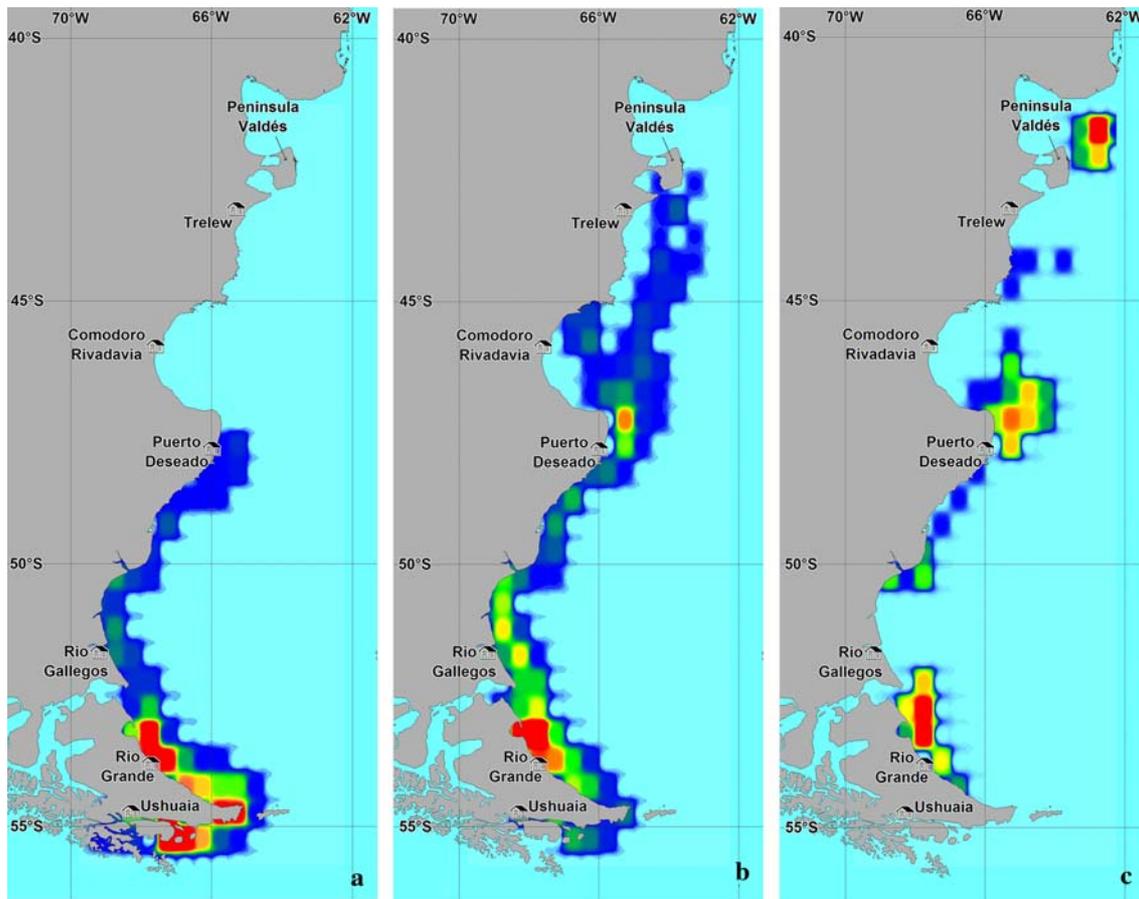
sion periods, and the lack of significant inter-annual differences apart from mean transmission periods, density distributions were created on a monthly basis to identify areas with a high accumulation of daily positions (Fig. 2).

**Fig. 1** Migration routes of magellanic penguins from Isla Martillo in **a** 2004 *Fips* = red (filled square), *Flo* = green (filled diamond), *Fyjima* = yellow (plus symbol), *Lu* = pink (filled circle), *Miriam* = blue (filled triangle), *Silvester* = brown (rectangle), *WaRu* = black (filled inverted triangle), **b** 2005 *Biggi* = black (filled circle), *Eggregius* = red (rectangle), *Eva* = brown (filled square), *Jennifer* = pink (filled diamond), *Jupp* = blue (filled triangle), *Schröder* = green (filled inverted triangle), *The Boss* = yellow (plus symbol), and **c** 2006 *Florian* = blue (filled circle), *Gimmy* = light blue (open rectangle), *Kira* = brown (filled diamond), *Klaus* = green (filled triangle), *NN1* = pink (filled inverted triangle), *NN2* = black (open rectangle), *NN3* = red (plus symbol), *Whitney* = yellow (filled square). The hatched coastal area between Peninsula Valdez and Tierra del Fuego indicates the “Patagonian tidal zone” as defined by Acha et al. (2004). For details see text



In April, highest bird densities were found in the eastern entrance of the Beagle Channel, around Cabo San Diego and to the north of Río Grande, just off the northeastern coast of Tierra del Fuego (Fig. 2). Only five penguins travelled further north and the northernmost position by the end

of April was near Puerto Deseado. During May, most other penguins travelled further north, but the area close to Río Grande was still frequented by four birds. Also, the coastal areas around Río Gallegos and north of Puerto Deseado, at the southern entrance of Golfo San Jorge, showed a high



**Fig. 2** Frequency distribution of daily positional fixes obtained from magellanic penguins in **a** March and April ( $n = 648$ ), **b** May ( $n = 452$ ) and **c** June ( $n = 136$ ). The colours represent the minimum number of

fixes obtained in one grid square ( $0.5^\circ$  latitude  $\times$   $0.5^\circ$  longitude); blue = 1 position, green =  $>2\%$ , yellow =  $>3\%$ , orange =  $>4\%$  and red =  $>5\%$  of all positions obtained during each month

density of daily positions. The birds furthest north by the end of May were located just south of the Península Valdés. By June, higher bird densities were still apparent in areas to the north of Río Grande, Puerto Deseado and also the Península Valdés. However, it should be noted that the progressive reduction in active transmitters, together with increasing distance from the breeding colony, meant that some of these areas were used by only one penguin over extended periods.

## Discussion

Potential impact of the satellite transmitters on the birds' behaviour and possible reasons for transmitter cessation

The external attachment of devices on free-ranging penguins is likely to have an impact on their behaviour (Bannasch 1995; Ropert-Coudert et al. 2007), because they increase the hydrodynamic drag (Bannasch et al. 1994), which in turn negatively impacts on a great variety of foraging parameters (e.g., Culik and Wilson 1991; Ropert-

Coudert et al. 2007). This effect is even more pronounced in transmitters equipped with an antenna, which itself further increases hydrodynamic drag (Wilson et al. 2004). However, several measures were taken in this study to reduce the impact of the devices on the penguins' behaviour (see "Materials and methods"). Furthermore, from 2005 onwards the position of the transmitters was moved further to the body centre following recent findings about implications of externally attached devices on the birds' balance (Chiaradia et al. 2005). Additionally, in 2006 smaller transmitter modifications were applied to three birds, which did not result in significantly prolonged transmitting periods. However, this is likely to be due to the small sample size, because the two longest, but also the shortest, transmitting periods were observed in these units.

Despite these measures, all devices ceased transmission during the course of the penguins' migration. Generally, cessation of transmission can occur for several reasons, either technical or biological. However, given the fact that the majority of devices ceased transmission after attachment periods of between 2 and 3 months, it is very likely that penguins detached the satellite transmitter by biting

and breaking the feathers attached to it (Wilson et al. 1997), which could be verified by the re-sighting of individuals in the breeding season following their winter migration. Therefore, we assume that the transmitters were not detrimental per se to the penguins and have not essentially altered the birds' behaviour, which is confirmed by comparable studies on the winter dispersal of magellanic (Pütz et al. 2000) and rockhopper penguins (Pütz et al. 2002b, 2006).

#### Migration patterns

Due to the location of the breeding site in the Beagle Channel, magellanic penguins could migrate into both the Atlantic and the Pacific Oceans. However, with only one exception all study birds headed eastwards into the Atlantic. Similarly, magellanic penguins originating from the Falkland/Malvinas Islands (51°S) and from Punta Tombo (44°S), Argentina, remained exclusively in the Atlantic during winter and migrated northwards, sometimes as far as the delta of the River Plate at 35°S (Stokes et al. 1998; Pütz et al. 2000). Only one of our study birds migrated into the Pacific, but then headed northwards as well. Thus, a northbound winter migration appears to be a general feature for magellanic penguins. In contrast, rockhopper penguins breeding on nearby Isla de los Estados distribute more equally around their breeding island in winter and even migrate as far south as the South Shetland Islands (Pütz et al. 2006).

Interestingly, the areas frequented by magellanic penguins from Isla Martillo were also used by conspecifics from other breeding sites, but earlier in the season as they did not have to travel so far to reach those areas during their northbound migration. For example, birds from the Falkland/Malvinas Islands (Pütz et al. 2000) used the same areas about one month earlier than their conspecifics from colonies further south (this study), resulting in a staggered effect. In addition, whereas birds from breeding sites located along the continent migrate exclusively along the coast (Stokes et al. 1998, this study), those from the Falkland/Malvinas Islands also use offshore areas and even the slope of the Patagonian Shelf for their northbound migration (Pütz et al. 2000). It is thus likely that magellanic penguins, due to the temporal and spatial differences in their migration patterns, experience qualitative and quantitative variations in food availability. Food availability has also been assumed to be responsible for coastal movements in other marine top predators such as humpback whales *Megaptera novaeangliae* (e.g., Acevedo et al. 2006), loggerhead turtles *Caretta caretta* (e.g., Luschi et al. 2006) and green turtles *Chelonia mydas* (e.g., Godley et al. 2003).

Unfortunately, nothing is known on the magellanic penguin diet during the winter months, but in summer variation

in the diet was observed depending on latitude, with penguins foraging in the north of their breeding range consuming primarily anchovy (*Engraulis anchovita*), whereas those further south preyed on a mixture of squid (*Loligo* spp. and *Illex* spp.), sprats (*Sprattus fuegensis*) and Hagfish (*Myxine* spp.) (Scolaro et al. 1999). In the Falkland/Malvinas Islands the diet also consists of a mixture of squid, fish and crustaceans, but the individual proportions are subject to large inter-annual variability (Pütz et al. 2001). However, the migration paths of the Magellanic Penguins coincided with the "Patagonian tidal zone" as defined by Acha et al. (2004) between the coastal waters from the north of the Peninsula Valdés (42°S) to Isla de los Estados (55°S) in the south. In this coastal zone, tidal fronts, where currents locally accumulate nutrients, occur temporarily in distinct areas over the Patagonian Shelf (e.g., Acha et al. 2004). Some of these fronts were also described by Sabatini et al. (2000) and have been predicted by Glorioso and Flather (1995). Subsequently, increased productivity promotes the formation of dense patches of marine plankton, which in turn enhances foraging opportunities for seabirds (e.g., Vlietstra et al. 2005). Thus, it can be assumed that magellanic penguins foraged predominantly in these areas during the study period. Furthermore, the northbound migration can also be related to decreasing sea temperatures and light levels during the study period, progressively impeding planktonic growth in more southerly regions as the season progressed. It thus appears that the northward migration of magellanic penguins during winter is driven by formation and subsequent dissipation of areas with enhanced food availability in this coastal zone. However, until mid-winter the food availability seems to be sufficient for at least a proportion of the birds in the far south as can be seen from magellanic penguins that remained at the northeastern coast of Tierra del Fuego in June (cf. Fig. 2).

#### Potential interactions with human activities

Exploitation of predominantly coastal areas by magellanic penguins also implies that they are increasingly exposed to human-related activities. The whole range of prey of magellanic penguins is commercially exploited and population crashes may happen due to poorly-managed fisheries (Scolaro et al. 1999). For example, magellanic penguin breeding success in two neighbouring colonies in southern Chile was significantly higher in the one not affected by fishing activities close-by (Radl and Culik 1999). A more direct threat derives from mortalities associated with the fishing itself. For example, in Puerto Quequén, Argentina, 100 magellanic penguins die each year as bycatch in coastal fishing (Tamini et al. 2002). Magellanic penguins also interact with shrimp fisheries at the Golfo San Jorge, either by incidental mortality in the fishing gear or by an overlap between the

bycatch of the fisheries and the diet of the penguins (Gandini et al. 1999).

Much more obvious effects on penguin survival result from oil pollution. More than 15,000 magellanic penguins died in 1991 as a consequence of a single oil incident (Williams 1995), whereas each year over 40,000 magellanic penguins die along the coast of the Argentine province Chubut due to chronic oil pollution (Gandini et al. 1994). Although shipping routes were moved 100 km further offshore in 1994, chronic oil pollution has increased since and the number of oiled penguins found along the coasts of Argentina correlates positively to the increasing amount of oil exported by Argentina (Borboroglu et al. 2006). In May 2006 this problem once again hit the headlines when several hundred magellanic penguins started to wash ashore at Argentina's Cabo Virgenes Nature Reserve in Patagonia, located just 80 km to the north of Río Grande; 224 could be treated, but an unknown number of penguins died. Despite the presence of several Argentine offshore oil platforms in the area, the source for the oil spill remained a mystery (Franklin 2006).

Given the northbound migration of magellanic penguins in winter, birds from remote colonies may interact with human activities located much further north. For example, along the coast between Salvador in southern Brazil and central Argentina, there are 30 large coastal cities (Brazil 21, Uruguay 1, Argentina 8), 49 oil ports (Brazil 43, Uruguay 1, Argentina 5) and government-owned oil company Petrobras operates nearly 100 offshore oil platforms in Brazil. In contrast, there are only seven coastal cities and five oil terminals in Patagonia, and only two coastal cities and three oil ports in Tierra del Fuego, although oil platforms are also located in the eastern section of the Magellan Strait and in waters extending further east. In particular the magellanic penguin breeding population located in the northern distributional range has decreased substantially over the past decades (Boersma et al. 1990), which may indicate harmful interaction with human activities. Opposing population trends and different migration patterns were also noted in another penguin species in the southwest Atlantic, the rockhopper penguin *Eudyptes c. chrysocome*, and have, at least partly, been attributed to increasing human activities on a latitudinal scale (Pütz et al. 2006). In fact, the area to the northeast of the coast of Tierra del Fuego was used simultaneously by magellanic penguins from Isla Martillo and rockhopper penguins (*Eudyptes c. chrysocome*) from Isla de los Estados (this study, Pütz et al. 2006). These waters contain the *Provincial Reserve Costa Atlántica de Tierra del Fuego*, a reserve of international interest devoted to migratory shorebirds. Given the fact that this reserve has not yet received fully protected status, our results, as well as those obtained by Pütz et al. (2006) on Rockhopper Penguins from Isla de los Estados, strongly support the

urgent need of special protection of these coastal waters and have consequently been made available to the respective authorities. However, due to their migration patterns, magellanic penguins from the southern distributional range would also benefit greatly from conservation measures imposed further north. To this end, data have also been fed into the databank held by the "Forum for the conservation of the Patagonian Sea and areas of influence" (for details see <http://www.sea-sky.org>) and forwarded to local conservation authorities to support the establishment of a protected "migration corridor" along the coast of the Argentine province of Chubut.

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