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Survival and movements of Magellanic penguins rehabilitated from oil fouling along the coast of South America, 2000–2010

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ABSTRACT

Oil pollution is a significant conservation concern. We examined data from six institutions along the coast of South America: Emergency Relief Team of the International Fund for Animal Welfare, Fundación Mundo Marino, Centro de Recuperação de Animais Marinhos, Natura Patagonia, Associação R3 Animal, and Mar del Plata Aquarium and data from resightings in Argentina, Brazil, Chile and Falkland/Malvinas Islands. From 2000 to 2010, 2183 oiled Magellanic penguins were rehabilitated as part of the routine activities of these institutions or during emergency responses to eight oil spills in which they were involved; all rehabilitated penguins were flipper banded and released. Since their release, 41 penguins were resighted until 31 December 2011. The results demonstrate that, when combined with other prevention strategies, the rehabilitation of Magellanic penguins is a strategy that contributes to the mitigation of adverse effects of oil spills and chronic pollution to the species.

1. Introduction

Magellanic penguins (*Spheniscus magellanicus*) are native to Argentina (south of 41°25′S), Chile (south of 29°S) and the Falkland/Malvinas Islands (approx. 51°45′S) (Williams and Boersma, 1995; Schiavini et al., 2005). During the austral winter, Magellanic penguins will migrate thousands of kilometres northward towards the coasts of northern Argentina, Uruguay and Brazil (Stokes et al., 1998; Pütz et al., 2000, 2007; Falabella et al., 2009). Juveniles will often reach southeastern Brazil (22°17′S) and, exceptionally, animals have been reported as far as northeastern Brazil (2°52′S) (Sick, 1997; García-Borboroglu et al., 2010).

Oil spills and chronic oil pollution (deliberate dumping of oil and bilge) are well-documented significant human-induced mortality factors for these birds during their breeding season and also during winter movements, with several hundred live and dead oiled penguins found ashore annually in South America (Gandini et al., 1994; Petry and Fonseca, 2002; García-Borboroglu et al., 2006; Rodrigues et al., 2010). A fraction of these birds make it alive to the shore and are admitted to rehabilitation centers or treated by emergency response teams, from which they are then rehabilitated, banded and released after meeting specific health criteria (Ruoppolo et al., 2004; García-Borboroglu et al., 2006; Heredia et al., 2008).

Rehabilitation following oiling has proven effective and relevant for the conservation of other penguin species (e.g. Randall et al., 1980; Underhill et al., 1997, 1999; Whittington, 1999, 2003; Giese et al., 2000; Goldsworthy et al., 2000a,b; Barham et al., 2006, 2007;

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Wolfaardt et al., 2008a,b,c, 2009). However, there is less information regarding the rehabilitation efforts of Magellanic penguins. Here we present resightings of Magellanic penguins that were rehabilitated from oiling along the coast of South America from 2000 to 2010.

2. Methods

Data from the rehabilitation efforts of six institutions were examined (Fig. 1a): Emergency Relief Team of the International Fund for Animal Welfare (IFAW); *Centro de Recuperação de Animais Marinhos* of the *Universidade Federal do Rio Grande* (CRAM-FURG), based in Rio Grande, and *Centro de Triagem de Animais Silvestres*, operated by the Environmental Military Police of Santa Catarina, IBAMA and *Associação R3 Animal* (R3A), based in Florianópolis, both on the southern coast of Brazil; *Fundación Mundo Marino* (FMM), based in San Clemente del Tuyú, and Mar del Plata Aquarium (MDPA), based in Mar del Plata, both on the northern coast of Argentina; and *Natura Patagonia* (NP), based in Punta Arenas, southern coast of Chile. IFAW responds worldwide to oil spills involving wildlife. CRAM-FURG, FMM, R3A, MDPA and NP respond regionally to wildlife affected by oil pollution.

Rehabilitation efforts by these institutions adopt internationally-recognized protocols (Callahan, 2001; Ruoppolo et al., 2004; Silva-Filho and Ruoppolo, 2007; Heredia et al., 2008), which may achieve 80–95% release rates for Magellanic penguins, depending on the circumstances (Heredia et al., 2007; Ruoppolo et al., 2007a). Penguins are released after meeting well-established criteria: perfect waterproofing of feathers, body condition score 3 or 4 (on a 1–4 scale), packed cell volume $\geqslant$38%, buffy coat <2%, total plasma protein $\geqslant$3 g/dL, absence of clinical signs of disease and of relevant lesions or wounds, normal behaviour. All released penguins included in this study were flipper banded with stainless steel bands on their left flipper (Fig. 2). Resightings were informed

Fig. 2. Penguin #02: rehabilitated during the Cabo Vírgenes spill in May 2006, airlifted and released in northern Argentina on 9 September 2006. Resighted 3 years later in November 2009, having travelled at least 1900 km back to the Cabo Vírgenes breeding colony. Image courtesy of Pablo Irazoqui – Consejo Agrario Provincial de Santa Cruz, Areas Protegidas.

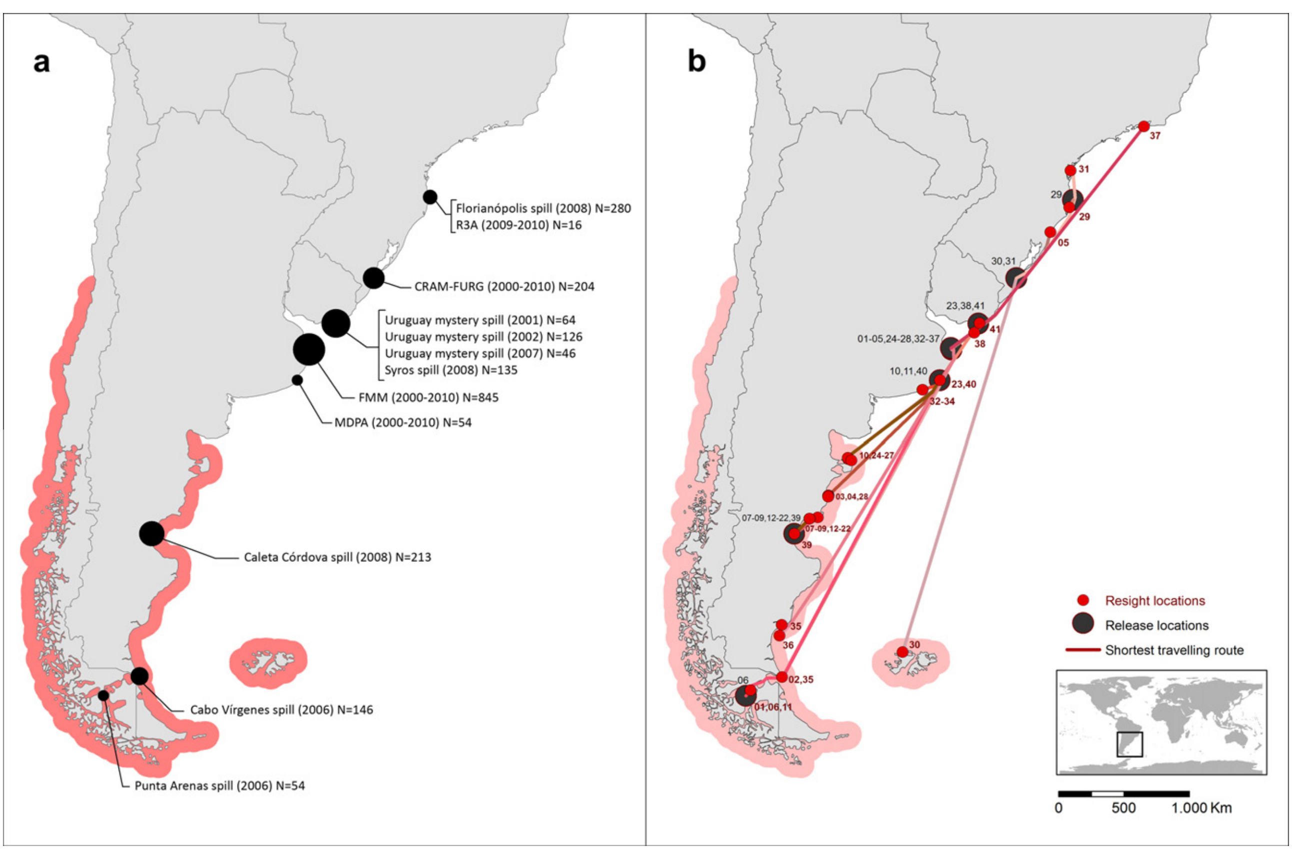

Fig. 1. Geographic distribution of: (a) institutions and oil spills, and number of oiled penguins that were rehabilitated, banded and released in each location; (b) release and resight locations and the shortest straight-line travel route. The breeding distribution of Magellanic penguins is shown in red (IUCN, 2011).

mainly through an online form (http://www.ifaw.org/penguin-band), direct communication from park rangers, fishermen and tourists, and reports from colleagues conducting long-term research programs on breeding colonies. Breeding colonies are referred to according to the nomenclature proposed by Schiavini et al. (2005).

The following parameters were examined on each bird treated by the five institutions: plumage on admission (juvenile or adult), oiling on admission (% of body surface coverage), body mass on admission (kg), body mass on release (kg), date of admission, date of release, date of resight, location of admission, location of release, location of resight, status on resight. The following body measurements were taken before release (*sensu* Bertellotti et al., 2002): bill length (cm), bill depth (cm) and elbow-to-tip flipper length (cm). Sometimes, additional data on body mass, behavior or feathering on resight were available. Gender was determined either from observation of breeding behavior (copulation or egg-laying) or from morphometric data (Bertellotti et al., 2002). Geographic Information Systems (GIS) was used to plot release and resight locations and an equidistant cylindrical projection was used to calculate the shortest travel distance between banding and resight/recovery locations (Datum WGS1984).

3. Results

The institutions rehabilitated, banded and released 2183 Magellanic penguins oiled from 2000 to 2010, including eight oil spills to which the institutions specifically responded (Fig. 1a, Table 1). Fig. 1b presents the locations where these birds were released and resighted and their shortest (straight-line) travel routes. Forty-one of these penguins (1.88%) had been resighted by 31 December 2011 (Fig. 2, Tables 2–4).

Shortest travel distance between release and resighting locations (mean ± SD) was 604 ± 673 km (range: 0–2160 km; $n = 41$). In 18 cases, the rehabilitated penguins travelled more than 500 km from the release location to where they were found; in 10 cases, more than 1000 km; in two cases, more than 2000 km. There was no linear relationship between the incident/institution mean shortest travel distance of its resighted animals and the resighting rate of that incident/institution (linear regression analysis; $R = 0.012$, $P = 0.765$); excluding the Cabo Vírgenes spill from that analysis (this incident was exceptional because animals were released thousands of kilometres away from the spill site, see Ruoppolo et al., 2007b) did not significantly change that result (linear regression analysis; $R = 0.010$, $P = 0.924$). The interval between release date and resight date was 789 ± 770 days (range: 8–3338 days; $n = 39$). In 12 cases, resightings occurred 2–3 years after release and in another 10 cases the penguins were resighted more than 3 years after release.

Resighted animals were identified as 4 males and 7 females that were juveniles at the time of admission, and 12 males and 14 females that were already in adult plumage upon admission; gender could not be determined for five animals (1 juvenile, 1 adult, 2 animals of undetermined age group). The overall gender ratio was 0.76 male per female, not significantly different from parity (one-proportion test; $P = 0.511$). Oil fouling affected 46 ± 29% of the body surface of the penguins that were resighted (range: 5–100%, $n = 34$). Body mass on admission was 3.24 ± 0.49 kg (range: 2.40–4.40 kg, $n = 35$), body mass on release was 3.93 ± 0.51 kg (range: 2.91–5.10 kg, $n = 37$), and body mass on resight was 3.35 ± 0.80 kg (range: 2.60–4.50 kg, $n = 8$). All animals had an increase in body mass during the rehabilitation period, in average 0.94 ± 0.50 kg (range: 0.06–2.08 kg; $n = 27$). Most animals for which there were data were found to have lost body mass during the interval from release to resight (86%); average body mass change from release to resight was −0.71 ± 0.90 kg (range: −1.90 to 0.86 kg; $n = 7$).

Thirty animals were alive when resighted (30/41; 73%). Live resightings were most frequently of penguins that had been admitted into rehabilitation as adults (24/30; 80%) compared to those admitted as juveniles (6/30; 20%) (Fisher's exact test; $P = 0.052$). Males (11/16; 69% alive) and females (18/21; 86% alive) were resighted alive in similar proportions (Fisher's exact test; $P = 0.254$). Among the deceased animals, most were considered to be migrating as they were found in winter (9/11; 82%) and the remaining were deceased shortly after release, during what may be considered an immediate post-sill adaptation period (2/11; 18%). Among the animals resighted alive, many were in active nests (13/30; 43%), either copulating (1/13; 8%), incubating (10/13; 77%) or rearing chicks (2/13; 15%); it was impossible to determine whether the eggs or chicks actually belonged to the resighted birds, however in most cases parental care was observed. Other animals resighted alive were migrating (3/30; 10%), molting (3/30; 10%), were in the colonies during the breeding season however did not appear to be breeding (1/30; 3%) or no information was reported regarding their association with nests (10/30; 33%).

4. Discussion

4.1. Admission details

The rehabilitated penguins had petroleum covering 5–100% of their body surface on admission. It is known that the extent of oiling does not have a strong impact on survival rates during rehabilitation, as any oil on the feathers leads to the loss of waterproofing

Table 1
Oiled Magellanic penguins rehabilitated, banded and released from 2000–2010.

Incident	Mean distance (km) from release to resight locations [min–max]	Mean resight interval (days) [min–max]	No. offlipper-banded penguins released	No. of penguins resighted
IFAW – Mystery spill, Uruguay (2001)	–	–	64	0 (0%)
IFAW – Mystery spill, Uruguay (2002)	381	1764	126	1 (0.79%)
NP – Punta Arenas spill, Chile (2006)	31	50	54	1 (1.85%)
IFAW - Cabo Vírgenes spill, Argentina (2006)	1192 [307–2070]	790 [26–1311]	146	7 (4.79%)
IFAW – Mystery spill, Uruguay (2007)	62	27	46	1 (2.17%)
IFAW – Caleta Córdova spill, Argentina (2008)	96 [0–127]	760 [34–1361]	213	15 (7.04%)
IFAW – Syros spill, Uruguay (2008)	4	8	135	1 (0.74%)
R3A / CRAM-FURG – Florianópolis spill, Brazil (2008)	66	10	280	1 (0.36%)
CRAM-FURG – Routine rehabilitation (2000–2010)	1470 [779–2160]	181 [89–272]	204	2 (0.98%)
FMM – Routine rehabilitation (2000–2010)	968 [792–1659]	1161 [23–3338]	845	9 (0.94%)
MDPA – Routine rehabilitation (2000–2010)	929 [928–1856]	921 [28–1554]	54	3 (5.56%)
R3A – Routine rehabilitation (2009–2010)	–	–	16	0 (0%)
Total	604 [0–2160]	789 [8–3338]	2183	41 (1.88%)

and consequently hypothermia, which is the main complication from oiling in penguins (Ruoppolo et al., 2004; Silva-Filho and Ruoppolo, 2007; Heredia et al., 2008; Rodrigues et al., 2010). Our results show that even extensively (i.e. 100% body cover) oiled penguins can recover successfully if subjected to appropriate rehabilitation procedures, and that the extent of oiled body surface is not an appropriate criterion to determine survival probability for rehabilitated Magellanic penguins. Other parameters such as packed cell volume or body mass on admission may be better criteria to determine survival probability of oiled penguins (Ruoppolo et al., 2004; Silva-Filho and Ruoppolo, 2007; Heredia et al., 2008; Rodrigues et al., 2010).

Most penguins have higher body mass on release than on admission. This is expected, as when admitted most penguins have starved for days if not weeks and are often emaciated (Ruoppolo et al., 2004; Silva-Filho and Ruoppolo, 2007; Heredia et al., 2008). Moreover, the elevated body mass on release is an aim of the rehabilitation procedures so to counterbalance high metabolic costs during the short-term post-release adaptation period (Ruoppolo et al., 2004; Silva-Filho and Ruoppolo, 2007; Heredia et al., 2008).

4.2. Survival and movements of oiled rehabilitated Magellanic penguins

Oiled Magellanic penguins subjected to recognized rehabilitation protocols have high pre-release survival rates (Heredia et al., 2007; Ruoppolo et al., 2007a; Adornes et al., 2008). Post-release survival, however, is much less studied. There is good scientific evidence in favour of the long-term success and post-release survival of oiled penguins (e.g. Randall et al., 1980; Underhill et al., 1997, 1999; Whittington, 1999, 2003; Giese et al., 2000; Goldsworthy et al., 2000a, 2000b; Barham et al., 2006, 2007; Wolfaardt et al., 2008a, 2008b, 2008c, 2009). Long-term monitoring studies of post-spill survival and reproduction are available for African penguins (*S. demersus*) (Randall et al., 1980; Underhill et al., 1997, 1999; Whittington, 1999, 2003; Barham et al., 2006, 2007; Wolfaardt et al., 2008a, 2008b, 2008c, 2009) and little penguins (*Eudyptula minor*) (Giese et al., 2000; Goldsworthy et al., 2000a, 2000b), which are relatively sedentary and determination of breeding location was possible. Such research, however, has not been conducted for Magellanic penguins due to biological and logistical reasons. Unlike African and little penguins, Magellanic penguins have one of the broadest seasonal movements amongst penguins, frequently traveling up to 2700 km away from their breeding colonies (Stokes et al., 1998; Pütz et al., 2000, 2002, 2007). Oiling often occurs during the winter movements, hundreds or thousands of kilometres away from the closest breeding colonies (García-Borboroglu et al., 2006).

Only three of the eight oil spills examined in this study occurred within the breeding range of Magellanic penguins: the Caleta Córdova, Cabo Vírgenes and Punta Arenas spills. The Caleta Córdova spill occurred in summer (December 2007), when Magellanic penguins were breeding and their foraging movements are limited to a few hundred kilometres from their breeding colonies (Stokes and Boersma, 1999; Pütz et al., 2002; Boersma et al., 2009). An estimated 1500 penguins breeding at the Isla Vernacci colonies (see García Borboroglu et al., 2002; Schiavini et al., 2005) likely encountered petroleum due to proximity of the breeding colony. Fourteen of the rehabilitated penguins were resighted approximately 100 km away, along Isla Vernacci, the nearest breeding colonies of northern San Jorge Gulf. Resighting frequency was 7.04%, the highest observed. The resightings of rehabilitated penguins occurred long after the spill, in most cases, more than 2.5 years post-release. The high number of resightings at Isla Vernacci reflects not only short-term post-spill survival, but is also evidence of longer-term survival with penguins possibly attempting to breed.

Similarly to the Caleta Córdova spill, the Cabo Vírgenes and Punta Arenas spills occurred within the species' breeding range. Both incidents occurred in May 2006, when it is winter and Magellanic penguins are often foraging hundreds of kilometres away from the breeding colonies (Stokes and Boersma, 1999; Pütz et al., 2000, 2002, 2007). It is not clear whether the Cabo Vírgenes and Punta Arenas incidents were isolated or if the Magellanic penguins became oiled from the same source spill, as there were oiled penguins washing up simultaneously at Cabo Vírgenes and Isla Magdalena colonies (Matus and Blank, 2007; Ruoppolo et al., 2007b). Air temperatures at the time were very low (reaching −14 °C) and significantly hindered rehabilitation efforts; as a consequence, the penguins from Cabo Vírgenes were airlifted to northern Argentina to finalize rehabilitation and released from there, nearly 1900 km from the spill location (Ruoppolo et al., 2007b). Despite the long-distance translocation, however, the penguins from the Cabo Vírgenes spill had the second highest resighting rate (4.79%), again suggesting that rescue in proximity to breeding colonies increases the probability of post-release resightings. Penguins from the Caleta Córdova spill and the Cabo Vírgenes spill were resighted, in most cases, more than 2.5 years after their release indicating long-term post-release survival.

Unlike the Caleta Córdova, Cabo Vírgenes and Punta Arenas spills, however, most oil spills that impacted Magellanic penguins did not occur in proximity to the species' breeding colonies. Moreover, there is no way to determine the colony of origin for Magellanic penguins (Bouzat et al., 2009) and, therefore, it cannot be predicted to where the penguin might return after being released. Relatively few of the species' breeding colonies are regularly monitored (Schiavini et al., 2005), and considering the species has a very large population – the population is estimated at approximately 1.6 million breeding pairs present in more than 130 breeding colonies (García-Borboroglu and Boersma, in press) – the odds of resighting a banded flipper are extremely unlikely. Moreover, it should be emphasized that resighting flipper banded penguins is an intensive effort, in which hundreds to thousands of flippers have to be observed to find just one banded penguin. Most resightings (21 of 38; 55%) occurred in locations in which there are long-term ecological research or monitoring programs that include intensive search for banded-birds, such as San Lorenzo, Punta Tombo, Isla Vernacci and Cabo Vírgenes (see Scolaro, 1987; Carribero et al., 1995; Schiavini et al., 2005; Wilson et al., 2005; Boersma, 2008), reflecting the uneven distribution of resighting efforts. There probably are numerous other rehabilitated penguins in other breeding colonies which remain unreported due to the lack of monitoring and visitation.

In many cases, the rehabilitated penguins travelled several hundred if not thousands of kilometres from the release location to where they were found, and resightings occurred a few years after release, suggesting rehabilitated oiled Magellanic penguins are able to survive for extended periods and swim across long distances after being released far from their breeding areas. Therefore, the argument that these penguins cannot be released after being rehabilitated in their wintering grounds because they would not be able to return to their breeding colonies may not be pertinent. Rehabilitated penguins have lower breeding success than those that never were oiled (Giese et al., 2000; Wolfaardt et al., 2008c), nonetheless, 13 Magellanic penguins had active nests at the breeding colony, suggesting some might have successfully bred. Two juvenile penguins (#27 and #28 in Tables 2–4) were oiled and rehabilitated and were found 8–9 years later in active nests.

4.3. Individual survival of rehabilitated Magellanic penguins

One Magellanic penguin (#30 in Tables 2–4) admitted for rehabilitation in southern Brazil was later found at Saunders Island,

Table 2
Date and location data of resighted Magellanic penguins.

ID	Flipper band	Incident	Admission Location	Admission date	Release location	Release date	Resight location	Resight date	Resight interval	Reported by
01	IF-0085	Cabo Vírgenes spill	Cabo Vírgenes, AR	03/05/2006	Punta Rasa, AR	10/08/2006	Isla Magdalena, CL	16/01/2007	5m 9d	Roberto Fernandez – CONAF, Ricardo Matus
02	IF-0141	Cabo Vírgenes spill	Cabo Vírgenes, AR	03/05/2006	Vivero, AR	09/09/2006	Cabo Virgenes, AR	18/11/2009	3y 2m 26d	Pablo Irazoqui – CAP
03	IF-0187	FMM routine rehab	San Clemente del Tuyú, AR	21/06/2007	Playa Norte, AR	21/07/2007	Punta Tombo, AR	14/10/2007	2m 25d	P. Dee Boersma – Univ. Washington
04	IF-0205	FMM routine rehab	San Clemente del Tuyú, AR	16/06/2007	Punta Rasa, AR	04/08/2007	Punta Tombo, AR	25/12/2009	2y 5m 4d	P. Dee Boersma – Univ. Washington
05	IF-0298	FMM routine rehab	San Clemente del Tuyú, AR	22/05/2009	Playa Norte, AR	14/08/2009	Praia do Curumin, BR	06/09/2009	23d	Leo Klein – Patrulha Ambiental RS
06	IF-0392	Punta Arenas spill	Punta Arenas, CL	N.R.	Punta Arenas, CL	14/07/2006	Isla Magdalena, CL	02/09/2006	1m 20d	CONAF through Ricardo Matus
07	IF-0495	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	27/01/2008	Is. Vernacci Norte 2, AR	28/10/2008	9m 5d	Pablo García-Borboroglu – CENPAT
08	IF-0499	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	27/01/2008	Is. Vernacci Norte 2, AR	06/11/2010	2y 9m 24d	Luciana Pozzi – CENPAT
09	IF-0500	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	08/02/2008	Is. Vernacci Norte 1, AR	06/11/2010	2y 9m 12d	Luciana Pozzi – CENPAT
10	IF-0525	MDPA routine rehab	Mar del Plata, AR	05/05/2007	Mar del Plata, AR	24/08/2007	San Lorenzo, AR	25/11/2011	4y 3m 4d	Agustina Gómez Laich – CONICET
11	IF-0536	MDPA routine rehab	Mar del Plata, AR	18/07/2007	Mar del Plata, AR	06/09/2007	Isla Magdalena, CL	01/12/2010	3y 3m 12d	Claudia Godoy, Roberto Fernandez – CONAF, Ricardo Matus
12	IF-0613	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	08/02/2008	Is. Vernacci Norte 2, AR	06/11/2010	2y 9m 12d	Luciana Pozzi – CENPAT
13	IF-0614	Caleta Córdova spill	Caleta Córdova, AR	04/01/2008	Rada Tilly, AR	08/02/2008	Is. Vernacci Norte 2, AR	28/10/2008	8m 23d	Pablo García-Borboroglu – CENPAT
14	IF-0643	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	09/02/2008	Is. Vernacci Norte 1, AR	08/11/2010	2y 9m 13d	Luciana Pozzi – CENPAT
15	IF-0653	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	09/02/2008	Is. Vernacci, AR	14/03/2008	1m 4d	Carla Poleschi – FPN
16	IF-0668	Caleta Córdova spill	Caleta Córdova, AR	04/01/2008	Rada Tilly, AR	09/02/2008	Is. Vernacci Norte 1, AR	30/10/2008	8m 24d	Pablo García-Borboroglu – CENPAT
17	IF-0677	Caleta Córdova spill	Caleta Córdova, AR	04/01/2008	Rada Tilly, AR	11/02/2008	Is. Vernacci Norte 1, AR	08/11/2010	2y 9m 11d	Luciana Pozzi – CENPAT
18	IF-0680	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	11/02/2008	Is. Vernacci Este, AR	27/10/2008	8m 19d	Pablo García-Borboroglu – CENPAT
19	IF-0699	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	11/02/2008	Is. Vernacci Norte 2, AR	03/11/2011	3y 8m 26d	Oscar Biagioni – online form
20	IF-0723	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	13/02/2008	Is. Vernacci Norte 2, AR	06/11/2010	2y 9m 7d	Luciana Pozzi – CENPAT
21	IF-0731	Caleta Córdova spill	Caleta Córdova, AR	12/01/2008	Rada Tilly, AR	13/02/2008	Is. Vernacci Norte 1, AR	06/11/2010	2y 9m 7d	Luciana Pozzi – CENPAT
22	IF-0746	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	19/02/2008	Is. Vernacci Norte 1, AR	06/11/2010	2y 9m 1d	Luciana Pozzi – CENPAT
23	MACN 53337	Uruguay mystery spill 2002	Maldonado, UY	01/07/2002	Maldonado, UY	08/09/2002	Mar del Plata, AR	08/07/2007	4y 10m 24d	Karen Griot – Mar del Plata Aquarium
24	A-0492	FMM routine rehab	San Clemente del Tuyú, AR	06/05/2005	Punta Rasa, AR	26/06/2005	San Lorenzo, AR	21/12/2008	3y 6m 14d	Luciana Pozzi – CENPAT
25	A-0753	FMM routine rehab	San Clemente del Tuyú, AR	13/05/2006	Punta Rasa, AR	31/07/2006	San Lorenzo, AR	11/01/2009	2y 5m 25d	Luciana Pozzi – CENPAT
26	A-0947	FMM routine rehab	San Clemente del Tuyú, AR	19/05/2006	Punta Rasa, AR	27/06/2006	San Lorenzo, AR	22/12/2008	2y 6m 9d	Luciana Pozzi – CENPAT
27	A-1206	FMM routine rehab	San Clemente del Tuyú, AR	11/08/2001	Playa Norte, AR	02/09/2001	Caleta Externa, AR	23/10/2010	9y 3m 8d	Luciana Pozzi – CENPAT
28	A-1276	FMM routine rehab	San Clemente del Tuyú, AR	23/09/2001	Punta Rasa, AR	26/10/2001	Punta Tombo, AR	25/12/2009	8y 3m 12d	P. Dee Boersma – Univ. Washington
29	W-16072	Florianópolis spill	Florianópolis, BR	N.R.	Ilha do Xavier, BR	07/10/2008	Garopaba, BR	17/10/2008	10d	Sidnei Caponi through CEMAVE
30	W-16477	CRAM routine rehab	Cassino Beach, BR	21/07/2010	Cassino Beach, BR	17/09/2010	Saunders Island, FK	15/12/2010	2m 29d	Suzan Pole-Evans
31	W-16650	CRAM routine rehab	Cassino Beach, BR	12/06/2008	Cassino Beach, BR	26/08/2008	Matinhos, BR	25/05/2009	9m 2d	Leandro Bugoni – FURG
32	IF-0022	Cabo Vírgenes spill	Cabo Vírgenes, AR	03/05/2006	Punta Rasa, AR	31/07/2006	Necochea, AR	26/08/2006	26d	Rodrigo Sierra through FMM
33	IF-????	Cabo Vírgenes spill	Cabo Vírgenes, AR	N.R.	Punta Rasa, AR	N.R.	Necochea, AR	26/08/2006	N.R.	Rodrigo Sierra through FMM
34	IF-????	Cabo Vírgenes spill	Cabo Vírgenes, AR	N.R.	Punta Rasa, AR	N.R.	Necochea, AR	26/08/2006	N.R.	Rodrigo Sierra through FMM
35	IF-0059	Cabo Vírgenes spill	Cabo Vírgenes, AR	03/05/2006	Playa Norte, AR	07/08/2006	Cabo Virgenes, AR	10/03/2010	3y 7m 21d	Juan Carlos Rea – online form
36	IF-0118	Cabo Vírgenes spill	Cabo Vírgenes, AR	03/05/2006	Playa Norte, AR	23/08/2006	Punta Quilla, AR	04/03/2010	3y 6m 29d	Fabian Caserma – online form
37	IF-0163	FMM routine rehab	San Clemente del Tuyú, AR	05/05/2007	Punta Rasa, AR	15/06/2007	Praia da Macumba, BR	27/08/2007	2m 13d	André Sena Maia – Niterói Zoo
38	IF-0485	Uruguay mystery spill 2007	Maldonado, UY	17/07/2007	Maldonado, UY	02/09/2007	Punta Negra de Portezuelo, UY	29/09/2007	27d	Luis Capezzolo – online form
39	IF-0497	Caleta Córdova spill	Caleta Córdova, AR	01/01/2008	Rada Tilly, AR	27/01/2008	Rada Tilly, AR	16/08/2010	2y 7m 2d	Macarena Milenio – online form
40	IF-0554	MDPA routine rehab	Mar del Plata, AR	07/05/2007	Mar del Plata, AR	28/09/2007	Mar del Plata, AR	26/10/2007	28d	Hugo Pablo Lertora – online form
41	IF-0761	Syros spill	Barra, UY	11/06/2008	Maldonado, UY	16/07/2008	Barra de Punta del Este, UY	24/07/2008	8d	Agustin Esteche – online form

N.R. = Not registered.

Table 3
Details of the resighted Magellanic penguins.

ID	Release coordinates	Resight coordinates	Shortest distance (km)	Gender	Plumage on admission	Bill depth (cm)	Bill length(cm)	Flipper length (cm)	Foot length (cm)	Oiling on admission	Mass on admission (kg)	Mass on release (kg)	Mass on resight (kg)	Resight status
01	36°17′S 56°46′W	52°55′S 70°35′W	2070	Male[a]	Adult	2.64	5.36	14.4	10.5	15%	3.25	4.83	N.R.	Live, molting
02	36°22′S 56°43′W	52°22′S 68°24′W	1910	Male[a]	Adult	2.22	5.82	15	10.5	10%	4.11	3.6	N.R.	Live, N.R.
03	36°21′S 56°44′W	44°02′S 65°13′W	1001	Female[a]	Adult	2.13	5.6	15.6	11.5	30%	2.4	3.5	N.R.	Live, active nest (copulating)
04	36°17′S 56°46′W	44°03′S 65°13′W	1008	Male	Juvenile	2.22	5.82	14.8	11.4	30%	2.65	3.64	4.5	Live, no active nest
05	36°21′S 56°44′W	29°35′S 49°55′W	854	Female[a]	Juvenile	1.9	4.66	13.9	11.5	20%	2.5	3.5	2.85	Live, migrating
06	53°59′S 70°48′W	52°55′S 70°35′W	31	Female[a]	Adult	1.9	5	N.R.	N.R.	N.R.	2.75	3.25	Poor condition	Live, N.R.
07	45°55′S 67°33′W	45°11′S 66°30′W	101	Female[a]	Adult	2	4.7	14.5	11	100%	3.68	3.36	N.R.	Live, N.R.
08	45°55′S 67°33′W	45°11′S 66°30′W	101	Female	Adult	2.1	5.2	14	12	40%	3.42	3.28	N.R.	Live, active nest (2 eggs)
09	45°55′S 67°33′W	45°11′S 66°30′W	101	Male	Adult	2.6	5.4	15	12	N.R.	N.R.	4.34	N.R.	Live, N.R.
10	38°04′S 57°32′W	42°05′S 65°50′W	932	Female	Juvenile	1.84	5.29	14.7	12	40%	2.6	4.07	Good condition	Live, N.R.
11	38°04′S 57°32′W	52°55′S 70°35′W	1856	Male[a]	Adult	2.26	5.82	15.6	11.5	25%	3	N.R.	4.45	Live, N.R.
12	45°55′S 67°33′W	45°11′S 66°30′W	101	Female	Adult	2.3	5.4	14	11.5	75%	3.61	3.76	N.R.	Live, active nest (1 egg)
13	45°55′S 67°33′W	45°11′S 66°30′W	101	Female[a]	Adult	2.2	5	14.5	11.5	50%	N.R.	3.68	N.R.	Live, active nest (2 eggs)
14	45°55′S 67°33′W	45°11′S 66°30′W	101	Male	Adult	2.5	5.6	14.5	12	50%	3.54	3.73	N.R.	Live, active nest (1 egg)
15	45°55′S 67°33′W	45°11′S 66°30′W	101	Male[a]	Adult	2.4	5.4	14	12	20%	3.36	3.46	N.R.	Live, pre-molt
16	45°55′S 67°33′W	45°11′S 66°30′W	101	Female[a]	Adult	2.2	5.4	15	12.5	70%	4.4	3.86	N.R.	Live, N.R.
17	45°55′S 67°33′W	45°11′S 66°30′W	101	Female	Adult	2.2	5.4	14	12	20%	3.744	3.6	N.R.	Live, active nest (2 eggs)
18	45°55′S 67°33′W	45°07′S 65°56′W	127	Male[a]	Adult	2.4	5.3	14	11.5	20%	3.54	3.6	N.R.	Live, N.R.
19	45°55′S 67°33′W	45°11′S 66°30′W	101	Female[a]	Adult	2.2	5.3	14.5	11.5	20%	3.820	4.4	Poor condition	Live, active nest (2 eggs)
20	45°55′S 67°33′W	45°11′S 66°30′W	101	Female	Adult	2.2	5	14	11.5	20%	3.3	4	N.R.	Live, active nest (2 eggs)
21	45°55′S 67°33′W	45°11′S 66°30′W	101	Female	Adult	2	5.4	15	11	75%	2.97	4	N.R.	Live, active nest (2 eggs)
22	45°55′S 67°33′W	45°11′S 66°30′W	101	Female	Adult	2.1	5.3	14.5	11	75%	3.48	3.4	N.R.	Live, active nest (2 eggs)
23	34°55′S 54°52′W	38°04′S 57°32′W	381	Male	Adult	2.43	5.85	14.7	11.8	25%	N.R.	4.1	2.7	Live, migrating
24	36°17′S 56°46′W	42°13′S 63°51′W	799	Unknown	Adult	N.R.	N.R.	N.R.	N.R.	50%	2.4	3.9	2.99	Live, active nest (1 egg, 1 chick)
25	36°17′S 56°46′W	42°09′S 63°52′W	792	Male[a]	Adult	2.32	6.1	15	11	50%	2.75	4	3.9	Live, N.R.
26	36°17′S 56°46′W	42°09′S 63°52′W	792	Male[a]	Adult	2.4	5.3	16	10.6	80%	3.2	4.3	N.R.	Live, N.R.
27	36°21′S 56°44′W	42°17′S 63°37′W	798	Female	Juvenile	N.R.	N.R.	N.R.	N.R.	50%	3	3.7	2.8	Live, active nest (2 eggs)
28	36°17′S 56°46′W	44°06′S 65°14′W	1008	Female	Juvenile	N.R.	N.R.	N.R.	N.R.	60%	3.2	4	N.R.	Live, active nest (2 chicks)
29	27°37′S 48°23′W	28°03′S 48°37′W	66	Female[a]	Juvenile	1.75	5.1	15	11	N.R.	2.79	N.R.	N.R.	Live, migrating
30	32°18′S 52°16′W	51°19′S 60°06′W	2160	Female[a]	Adult	2.2	5.65	15.8	12.6	75%	3.024	3.752	N.R.	Live, molting
31	32°18′S 52°16′W	25°49′S 48°32′W	779	Male[a]	Juvenile	2.1	5.65	15.2	12.2	80%	3.182	4.65	N.R.	Dead, migrating
32	36°17′S 56°46′W	38°35′S 58°43′W	309	Male[a]	Adult	2.28	5.6	14.5	11	5%	3.88	4.92	N.R.	Dead (gillnet), migrating
33	36°17′S 56°46′W	38°35′S 58°43′W	307	Unknown	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	Dead (gillnet), migrating
34	36°17′S 56°46′W	38°35′S 58°43′W	307	Unknown	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	Dead (gillnet), migrating
35	36°21′S 56°44′W	50°36′S 68°34′W	1740	Male[a]	Adult	2.4	5.7	14.5	11.6	5%	3.44	4.55	N.R.	Dead (gillnet), migrating
36	36°21′S 56°44′W	50°07′S 68°25′W	1700	Female[a]	Adult	2.2	5.26	14.5	11	5%	3.02	5.1	N.R.	Dead, migrating

Table 3 (*continued*)

ID	Release coordinates	Resight coordinates	Shortest distance (km)	Gender	Plumage on admission	Bill depth (cm)	Bill length(cm)	Flipper length (cm)	Foot length (cm)	Oiling on admission	Mass on admission (kg)	Mass on release (kg)	Mass on resight (kg)	Resight status
37	36°17′S 56°46′W	23°02′S 43°29′W	1659	Male[a]	Juvenile	2.15	5.9	15.5	12	100%	3.5	4.5	2.6	Dead, migrating
38	34°55′S 54°52′W	34°87′S 55°10′W	62	Male[a]	Juvenile	2.17	6.04	16.5	N.R.	25%	3.45	4.52	N.R.	Dead, migrating
39	45°55′S 67°33′W	45°55′S 67°33′W	0	Female[a]	Juvenile	2.2	5	13.5	12	90%	3.7	2.91	N.R.	Dead, migrating
40	38°04′S 57°32′W	38°04′S 57°32′W	0	Female[a]	Juvenile	1.99	4.94	14	10.5	90%	2.6	4.15	N.R.	Dead, post-spill adaptation
41	34°55′S 54°52′W	34°54′S 54°48′W	4	Unknown	Juvenile	N.R.	N.R.	N.R.	N.R.	N.R.	3	3.52	Good condition	Dead, post-spill adaptation

N.R. = Not registered.
[a] Gender determined from morphometrics.

Table 4
Additional details of some resighted Magellanic penguins.

ID	Resight comments
01	Resighted twice (pre-molt on 16/01/2007 and molting on 28/02/2007).
04	Wandering at colony
05	Twisted beak (congenital defect?). Found alive, debilitated (wing-walking), good body condition. Sent to CRAM-FURG, re-released in October/2009 but returned to the same location shortly after and died
06	Poor health condition, died hours later
11	Resighted in the same location on 08/12/2010, 22/01/2011, 08/02/2011 and 30/10/2011, incubating at nest on the resighting; skin cut due to the flipper band, which was removed and replaced by a web tag #12635 on 08/02/2011 (Claudia Godoy, pers. comm.)
14	Resting on rocks
21	Re-oiled (25%) on resight. Rehabilitated and released once again on 22/08/2007, this time with satellite tag which tracked the animal traveling directly towards Punta Tombo, AR, not landing then following southwards to Puerto Deseado, AR, until transmissions ceased after 51 days (11/10/2007) (see Boersma, 2012)
30	Dead in a group of 54 dead penguins (three of which had flipper bands), gillnet fishery by-catch
31	Dead in a group of 54 dead penguins (three of which had flipper bands), gillnet fishery by-catch
32	Dead in a group of 54 dead penguins (three of which had flipper bands), gillnet fishery by-catch
33	Dead in gillnet fishery by-catch
35	No wounds, not oiled, pododermatitis lesions still visible
37	Only the flipper was found close to the beach

Falkland/Malvinas Islands, showing that Magellanic penguins from the Falkland/Malvinas Islands share wintering areas with those used by penguins from the South American coast (Pütz et al., 2000). Two other individuals (#01 and #11) released in northern Argentina were found on Isla Magdalena, southern Chile, exemplifying that populations of Magellanic penguins using northern Argentinean waters share the Strait of Magellan with southernmost populations.

Three penguins (#32, #33, #34) that had been rehabilitated from the Cabo Vírgenes spill were caught together and died in a gillnet 26 days after their release along with 51 unbanded Magellanic penguins, suggesting the three rehabilitated penguins had successfully joined a group of penguins shortly after release, with which they had been foraging.

Two juvenile penguins (#05, #28) were resighted in poor health shortly after release (23 days and 10 days, respectively), one of which (#05) had swum at least 854 km from its release location. Another three juvenile penguins (#38, #40, #41), were found dead less than one month after release within 70 km distance of the release location. These penguins probably failed to cope during the first month of post-release adaptation (Wolfaardt et al., 2009).

One Magellanic penguin (#23) was oiled during the Uruguay mystery spill in July 2002 and released at the same location in August 2002. This penguin was found once again oiled 4 years later in Mar del Plata, Northern Argentina in August 2007. It was rehabilitated once more and released with a satellite tracker. During the following 51 days, this penguin headed south toward the Province of Chubut where it, remained foraging for a short period then followed southwards towards Puerto Deseado, southern Argentina, when the transmissions ceased (Boersma, 2012).

4.4. Effects of flipper bands on rehabilitated Magellanic penguins

There is extensive evidence on the negative effects of flipper bands to different species of penguins (Gauthier-Clerc et al., 2004; Petersen et al., 2005; Ainley, 2004; Saraux et al., 2011). Studies conducted on Magellanic penguins have failed to identify significant impacts on foraging behaviour or reproductive success, but found elevated mortality particularly on the first-year post-banding (Boersma and Rebstock, 2009, 2010). Despite these negative effects and the previously discussed difficulties in resighting banded birds, the results presented in this study demonstrate the importance of flipper banding to monitor post-release survival and movements of rehabilitated penguins. Currently, banding may be the only feasible strategy to monitor high numbers of rehabilitated birds after release and to obtain any information on post-release survival and movements. Post-spill rehabilitation monitoring of nearby breeding colonies should also be considered a relevant part of the oil spill response recovery plan, to assure proper assessments of post-release survival of rehabilitated animals and of long-term impacts of the spill. Satellite tracking studies would be most welcome to further elucidate post-release movements and survival of rehabilitated penguins (e.g. Stokes and Boersma, 1999; Pütz et al., 2000, 2002, 2007), however it must be kept in mind that this method is limited by its relatively high costs and its potential interference with the penguins' behaviour (Wilson et al., 2004).

5. Conclusion

The long-term success of Magellanic penguin rehabilitation efforts will only be accurately determinable when a greater fraction of the species' breeding colonies are extensive and intensively monitored in search of bands. Even then, the success of rehabilitation in terms of penguin survival may be underestimated, as penguins that remain at sea are not sighted. While the implementation of preventive measures, policies and surveillance should remain priorities in the reduction of negative impacts of oil exploitation on seabirds and more research is advised to monitor its effects, our results demonstrate – and corroborate with experience on African penguins (Randall et al., 1980; Underhill et al., 1997, 1999; Whittington, 1999, 2003; Barham et al., 2006, 2007; Wolfaardt et al., 2008a, 2008b, 2008c, 2009) – that rehabilitation of Magellanic penguins is a strategy that contributes to the mitigation of adverse effects of oil spills and chronic pollution of Magellanic penguins.

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