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Population trends of the Southern Rockhopper Penguin (*Eudyptes chrysocome chrysocome*) at the northern limit of its breeding range: Isla Pingüino, Santa Cruz, Argentina

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Abstract During the last century, there has been a steady decline in the global breeding population of *Eudyptes chrysocome chrysocome*, and this species has been exposed to many different threats. However, the small breeding population of Isla Pingüino, Argentina, increased since its discovery in 1985 until 1990. To determine whether this population continued to grow, we assessed its trend over a 30-year period and estimated its breeding success. This study shows a strong increase in the population in Isla Pingüino with an annual growth rate of more than 7 %, throughout the 30-year study period. The threats that are affecting seabird populations in other areas seem to have no negative effects on this breeding population. In particular, tourism, which has grown exponentially during the survey period, appears to not have had a negative effect on the settlement of new pairs, the number of breeding pairs and their breeding success. We suggest that the population increase in Isla Pingüino might have been facilitated by an immigration of breeding adults from nearby breeding sites such as Falkland Islands (Malvinas).

Keywords *Eudyptes chrysocome chrysocome* · Southern Rockhopper Penguin · Population trends · Isla Pingüino · Argentina

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Introduction

Seabirds are key components of the marine ecosystem, and assessing their population trends, productivity and threats is essential for their conservation. The Rockhopper Penguin, *Eudyptes chrysocome,* has a circumpolar distribution, breeding on sub-Antarctic and temperate islands from 46° to 54° south, and comprises two subspecies. *E. c. chrysocome* breeds in the Atlantic Ocean (Fig. 1) on the Falkland Islands (Malvinas) (hereafter referred to as FI–M), where it is found in 55 different colonies (with a total of 210,418 breeding pairs in 2005), Isla Pingüino, Isla de los Estados and on a number of offshore islands in the Pacific Ocean, southern Chile (Schiavini et al. 2005). *E. c. filholi* breeds in the sub-Antarctic islands of the Indo-Pacific Ocean (Thomson and Sagar 2002; Pütz et al. 2013). The population trend of *E. c. chrysocome* is not clear, and the species is probably exposed to several potential threats (Pütz et al. 2002; BirdLife International 2010). Part of its breeding population has been declining: The colonies in FI–M showed a 30 % decrease over a 10-year study (1995–2005; Bingham 1998; BirdLife International 2010; but see Baylis et al. 2013), and the Staten Island population decreased in 24 % over 12 years of study between 1998 and 2010 (Raya Rey et al. 2014). The trend of the Chilean population, on the other hand, remains unknown (Pütz et al. 2013).

Contrary to these overall declining trends, the small breeding population of Isla Pingüino, Argentina, has been increasing. Frere et al. (1993) described this colony and some general aspects of its breeding biology and monitored the population trend between 1985 (year of its discovery) and 1990. During this period, the island held only one breeding site of around 200 breeding pairs, which showed an average annual growth rate of 27 % (Frere et al. 1993).

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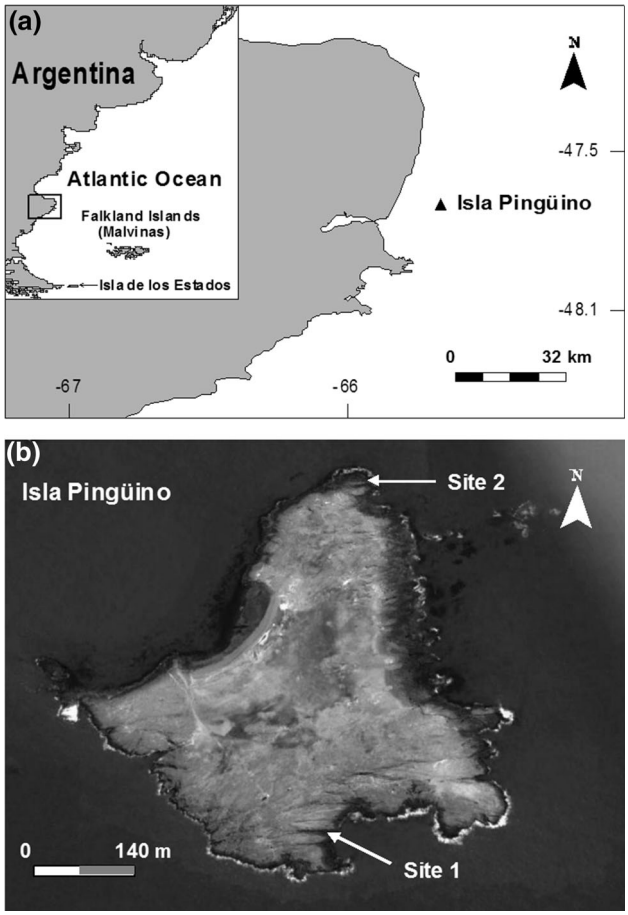

Fig. 1 **a** Geographical location of the islands hosting breeding Rockhopper Penguins in the South Atlantic Ocean, **b** breeding sites (1 and 2) of the Southern Rockhopper Penguins at Isla Pingüino *Satellite image source*: Data SIO, NOAA, US Navy, NGA, GEBCO. Image © 2016 DigitalGlobe

Due to its global population decline, *Eudyptes chrysocome* has been listed as Vulnerable according to the IUCN criteria (BirdLife International 2014). The exact causes of this decline are not known, but several potential causes have been identified: tourism, land-based predation, pandemic diseases, pollution, interactions with fisheries and climate change (Gandini et al. 1999; BirdLife International 2010; Dehnhard et al. 2013). Some of these threats do not seem to be of concern in our study site; these are land-based predation (personal observation), pandemic diseases (Karesh et al. 1999) and pollution (Gandini et al. 1994). As far as we know, there is no evidence of changes in the oceanographic features (sea surface temperature or primary productivity) of the waters around our study area; however, this factor cannot be discounted without better corroboration.

Fishing has expanded rapidly around FI–M since the mid-1970s, eventually threatening fish and squid stocks (Patterson 1987), some of which are prey of Penguins (Frere et al. 1996; Ciancio et al. 2008). The waters off the northern coast of Santa Cruz Province are important feeding grounds for breeding and wintering Southern Rockhopper Penguin from the Southwest Atlantic (Pütz et al. 2003, 2006). However, no evidence of Rockhopper Penguin interaction was found in the northern coast of Santa Cruz province where the shrimp fishery is taking place (Gandini et al. 1999; Marinao and Yorio 2011).

Tourism is an important growing industry throughout the species' distribution range (Ingham and Summers 2002), but the impact on its breeding population is unknown. In the Magellanic Penguin, *Spheniscus magellanicus*, another Penguin species that breeds in the area, current information shows that tourism is compatible if appropriately managed, with little impact on breeding birds (Yorio et al. 2001).

To determine whether the population at Isla Pingüino continued to grow since its discovery, we assessed its population trend over a 30-year period. We also estimated the breeding success of birds at this site. Last, we discuss the potential threats, with a focus on tourism that might affect the Rockhopper Penguin population at Isla Pingüino.

Methods

Between 1985 and 2014 breeding seasons, we collected information on breeding *E. c. chrysocome* at Isla Pingüino, an island located within Isla Pingüino Marine National Park, 25 km off Puerto Deseado, in the Santa Cruz Province, Argentina (Fig. 1). Two breeding sites were surveyed: Site 1 (47°54′52.5″ S; 65°43′4.0″ W), which was discovered in 1985 and described by Frere et al. (1993), and Site 2 (47°54′ 22″ S; 65°42′59″ W) a new settlement discovered in 1998 (see results), located 900 meters from Site 1 (Fig. 1).

We visited and surveyed the entire island almost every year looking for new settlements. During each breeding season, we visited the sites twice. The first visit took place at the beginning of December, during late incubation period (Frere et al. 1993; Schiavini et al. 2005), in order to count breeding pairs. At this time, one or two surveyors conducted direct counts of breeding pairs (counted when at least one Penguin was sitting on the nest) with the help of a manual counter. We conducted only one count in each year studied. The second visit was at the end of January, during late chick-rearing stage, in order to count all the grown chicks. The chicks, gathered in packed or loose crèches, were also monitored by direct counts with the help of a manual counter (with one count in each year studied, between 2001 and 2014). The annual reproductive success was calculated for each site and year, as the ratio of the number of grown chicks to the number of breeding pairs,

expressing therefore the average number of grown chicks per breeding pair.

We analyzed population trends for both sites together and separately. To detect the overall population trend of Rockhopper Penguins at Isla Pingüino (the two sites combined), available time series were modeled using the program TRIM (Trends and Indices for Monitoring Data; Pannekoek and van Strien 2005). We used a model with a site effect and a linear (on the log-scale) effect of time.

Annual population rate of change for the entire population and for each site separately was calculated as:

$$r = \ln(\lambda) = \ln(N_{t+1}/N_t)$$

where N_t is the number of pairs breeding at time t, N_{t+1} is the number of pairs breeding at time t + 1, and λ is the population growth rate (Caughley 1977; Sibly and Home 2002). N_t and N_{t+1} were given by TRIM as inputted counts (observation plus estimated values for missing counts).

We also evaluated what type of growth curve best fits our data. We fitted the data to both an exponential and linear regression and analyzed their adjustment.

With regard to the potential impact of tourism, we compiled the number and period of visits, and the number of visitors, of the main tourism company. We also participated on some tours (at least 2 per year) to observe their implementation and guidelines.

Results

The annual breeding pair counts and the reproductive success estimates are shown in Table 1. The second breeding site (Site 2) was discovered in December 1998 and held 28 breeding pairs on that year. The Penguins could have started to settle at this new site some years before this 1998 survey, as the area of Site 2 was not visited in 1996 and 1997, but was visited in 1995, with no breeding pairs registered at that time. The largest counts of breeding pairs were 1061 for Site 1 and 44 for Site 2 (both during the 2014 breeding season).

Between 1985 and 2014, the breeding population of Rockhopper Penguins showed an increase of 7.7 % per year (TRIM estimates: overall multiplicative slope = 1.0768 ± 0.005, $p = 0.01$). The TRIM model indicated that, over this period, the estimated total breeding pairs increased from 81 ± 19 to 1105 ± 73 (Fig. 2). Both sites showed similar average population rates of change: Site 1 average $r = 0.089$; Site 2 average $r = 0.070$. The population at Site 1 increased 1209 %, during a 30-year period. The number of pairs at Site 2 increased from 28 to 44, representing an increase of 57 % during a 17-year period of time. The number of breeding pairs at each site and for the entire island population (two sites together; Fig. 2) fitted to an exponential growth curve ($R_{site\ 1} = 0.98$, $R_{site\ 2} = 0.88$, $R_{whole\ population} = 0.98$).

Between the 2001 and 2014 breeding seasons, the mean annual reproductive success was 0.54 ± 0.09 of grown chicks per breeding pair ($n = 14$); range (0.41–0.75). These values are consistent with those found in FI–M: 0.35–0.61 (Clausen and Pütz 2003) and 0.69 (Poisbleau et al. 2008), and in Staten Island: 0.23–0.31 (Raya Rey et al. 2007).

Tourism

Site 1 was visited by one local tourist agency in most cases. The visits to the colony were always made in the company of a specialized guide, and tourists were allowed within approximately 2 meters of the Penguins to take photographs. This agency started visiting the island soon after the discovery of the colony in 1985, first occasionally and with few visitors, and then every year more frequently and with more visitors (Table 2). Group sizes were always small (usually around 8–15 visitors) and never exceeded more than 30 visitors at any one time and per day. Tourism showed an exponential growth in the frequency of visits ($R = 0.819$; $n = 12$) and number of visitors ($R = 0.824$; $n = 12$) between 1998 and 2009.

Discussion

The population trends of Southern Rockhopper Penguins of South America show variation with respect to the location and the period of time assessed. In FI–M, a 30 % decline was reported between 2000 and 2005 by Huin (2006), followed by a 36 % increase between 2005 and 2010 (Baylis et al. 2013). Nevertheless, the number of breeding pairs in 2010 was slightly greater than in 2000 (Baylis et al. 2013). Staten Island has a population of nearly 127,000 pairs showing an annual decline of 2.22 % (Raya Rey et al. 2014), and the Chilean population trend is unknown (Pütz et al. 2013). The steep population growth at Isla Pingüino does not outweigh the unclear trends and the dramatic declines found throughout the species' range; hence, the results of this study should not affect the classification of the Rockhopper Penguin as a globally threatened species according to IUCN criteria (BirdLife International 2014).

This study shows a steep population increase with an average annual rate of more than 7 % along the 30-year study period and the finding of a new breeding site. Some studies related the positive trend from the FI–M of the last 15 years with the high survival rate of juveniles and adults, linked to favorable water temperatures in foraging waters around the FI–M (Baylis et al. 2013; Dehnhard et al. 2013). But, while the population in FI–M showed a 36 % increase,

Table 1 Number of breeding pairs and reproductive success of Rockhopper Penguins Eudyptes chrysocome chrysocome at Isla Pingüino, Santa Cruz, Argentina

Years	Number of pairs site 1	Number of pairs site 2	Reproductive success grown chicks/breeding pairs
1985	81	–	–
1986	61	–	–
1987	142	–	–
1988	175	–	–
1989	270	–	–
1990	199	–	–
1994	180	–	–
1998	237	28	–
1999	221	29	–
2000	298	30	–
2001	348	31	0.46
2002	360	32	–
2003	353	26	0.41
2004	387	27	0.53
2005	393	25	0.52
2007	477	24	0.58
2008	521	27	0.52
2009	588	29	0.59
2010	770	35	0.55
2011	818	32	0.41
2013	913	41	0.75
2014	1061	44	0.68

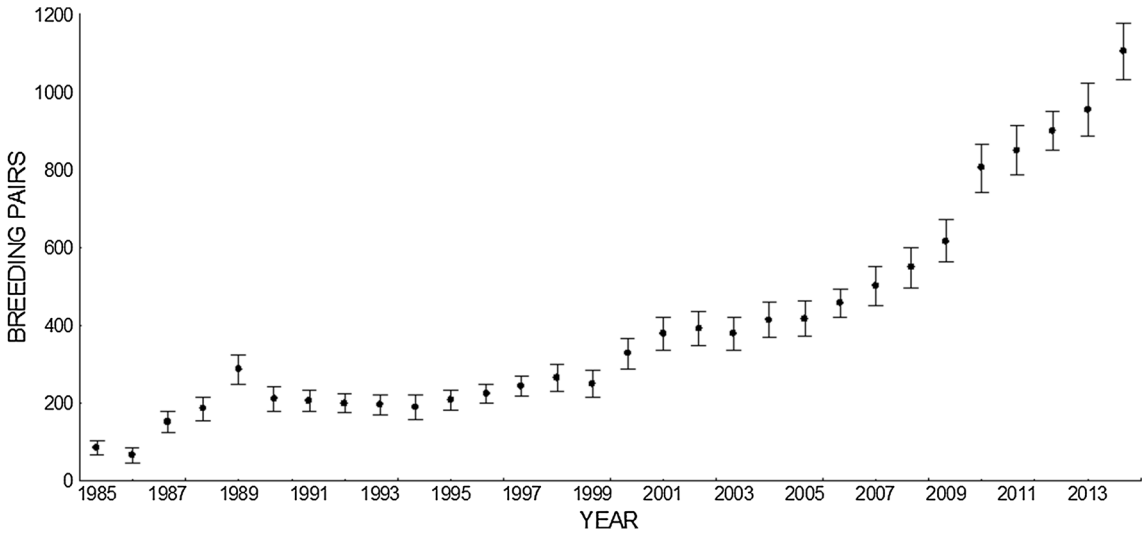

Fig. 2 Estimates of annual breeding population of Southern Rockhopper Penguins from 1985 to 2014. *Black dots* indicate the number of annual breeding pairs for the entire population at Isla Pingüino. Estimates were given by TRIM as inputted counts. *Error bars* indicate ±SE

Isla Pingüino registered a 92 % increase (2005–2010). Considering that the feeding grounds of both populations partially overlap, particularly during the non-breeding season (Pütz 1998; Falabella et al. 2009), we would expect both populations to be affected in a similar way during the same period of time. Nevertheless, between 1995 and 2005, while the colonies in FI–M decreased, Isla Pingüino showed a sharp population growth. On the other hand, the

Table 2 Number of visitors and number of tourist trips to Isla Pingüino, Santa Cruz Argentina

Years	Number of trips	Number of visitors
1998	5	40
1999	3	35
2000	8	57
2001	10	64
2002	6	41
2003	19	129
2004	25	109
2005	13	86
2006	15	98
2007	37	372
2008	45	461
2009	48	612

breeding success at both Isla Pingüino and FI–M was very similar. Accordingly, we suggest that the population increase in Isla Pingüino might have been facilitated by an immigration of breeding adults from nearby breeding sites such as FI–M. Furthermore, given that juvenile Penguins suffer a high mortality during the first year and that the species shows a delayed age of first breeding (4–5 years; Williams 1995) and low breeding success (around 0.5 chicks/pair in this study), we consider that this stark growth rate at Isla Pingüino was not obtained only by its intrinsic growth. Nevertheless, further studies, including genetic comparisons, are needed to confirm the immigration hypothesis.

The environmental threats that have been affecting Rockhopper Penguin populations in other areas (BirdLife International 2010; Pütz et al. 2013) do not seem to affect the breeding population of Isla Pingüino. In particular, tourism, which has grown exponentially during the survey period, appears to have no negative effect, so far, on the settlement of new pairs, the number of breeding pairs and the breeding success of the colonies studied. Colonies in the FI–M receive the most visitors, although only some colonies such as New Island and West Point Island receive very large numbers of tourists (e.g., 5000–10,000 passengers cruise ships), while the Southern Rockhopper Penguin breeding sites in Argentina receive only small-scale tourism (Pütz et al. 2013). Likewise, the fisheries do not seem to be affecting the Rockhopper Penguin breeding population of Isla Pingüino. The Rockhopper Penguins of Isla Pingüino are feeding on a mix of sprats (*Sprattus fuegensis*), small crustaceans (euphausiids) and cephalopods (*Loligo gahi*) (Gandini and Frere unpublished data; BirdLife International 2010), and none of these prey species are targets of the local fisheries. On the other hand, Rockhopper Penguin bycatch is infrequent, with only one individual recorded in 10 years of observed fisheries in the central and northern Patagonia area (Gandini unpublished data; Raya Rey and Schiavini 2005). Although climate change and variability of oceanographic conditions are considered important threats for the species, they seem not to affect negatively the trend of Isla Pingüino population.

In the FI–M, the Rockhopper Penguins seem to be under additional threats. A large-scale seabird mortality event (caused by paralytic shellfish poisoning) occurred in November 2002, involving large numbers of many seabird species, including Rockhopper Penguins (Pütz et al. 2013). The presence of feral mice and rats in some breeding sites of the FI–M could also be affecting breeding success of the Penguins (Quillfeldt et al. 2008). Furthermore, chronic oil pollution is another threat for Rockhopper Penguins around the FI–M (Pütz et al. 2013). Shortage of food related to adverse oceanic conditions induced a heavy and widespread mortality during the 1985–86 breeding season in the FI–M and a dispersion and mortality event along the Patagonian coast (Boersma 1987; Keymer et al. 2001). A similar dispersion and mortality event along the Patagonian coast, probably of analogous origin, took place during late summer 2016 (Morgenthaler et al. unpublished data). Therefore, the changes in oceanographic parameters along with the other additional threats around the FI–M may support the hypothesis of Penguin emigration from these breeding grounds toward other sites and may in this way affect positively the population trend of Isla Pingüino.

The waters around Isla Pingüino are important feeding grounds for the FI–M and Isla Pingüino Rockhopper Penguin populations (Pütz et al. 2002, 2006), and fortunately, Isla Pingüino and its surrounding waters became protected under national law since the creation of a Marine National Park in 2012. Our study confirms the value of this area as it contains the only Southern Rockhopper Penguin population continually increasing during the last decades.

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