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Research Paper

Population Trends of a Mixed-Species Colony of Humboldt and Magellanic Penguins in Southern Chile after Establishing a Protected Area

Tendance d'une colonie mixte de Manchots de Humboldt et de Manchots de Magellan dans le sud du Chili à la suite de l'établissement d'une aire protégée

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ABSTRACT. Worldwide marine protected areas (MPAs) have been designated to protect marine resources, including top predators such as seabirds. There is no conclusive information on whether protected areas can improve population trends of seabirds when these are further exploited as tourist attractions, an activity that has increased in past decades. Humboldt Penguins (*Spheniscus humboldti*) and Magellanic Penguins (*S. magellanicus*) breed sympatrically on Puñihuil Islets, two small coastal islands off the west coast of Chiloé Island (41° S) in southern Chile that are subject to exploitation for tourism. Our goal was to compare the population size of the mixed colony of Humboldt and Magellanic Penguins before and after protection from unregulated tourism and freely roaming goats in 1997. For this purpose, two censuses were conducted in 2004 and 2008, and the numbers compared with those obtained in 1997 by other authors. The proportion of occupied, unoccupied, and collapsed/flooded burrows changed between years; there were 68% and 34% fewer collapsed burrows in 2004 and 2008, respectively, than in 1997. For the total number of burrows of both species, we counted 48% and 63% more burrows in 2004 and 2008, respectively, than in 1997. We counted 13% more burrows of Humboldt Penguins in 2008 than in 1997, and for Magellanic Penguins, we estimated a 64% increase in burrows in 2008. Presumably, this was as a result of habitat improvement attributable to the exclusion of tourists and the removal of goats from the islets. Although tourist visits to the islets are prohibited, tourism activities around the colonies are prevalent and need to be taken into account to promote appropriate management.

RÉSUMÉ. Les aires marines protégées ont été établies à l'échelle mondiale pour protéger les ressources marines, dont les prédateurs au sommet de la chaîne alimentaire comme les oiseaux marins. Rien n'indique de façon concluante que la protection d'aires permet une hausse des populations d'oiseaux marins dans les cas où ces populations représentent toujours une attraction touristique, activité dont la popularité a augmenté au cours des dernières décennies. Les Manchots de Humboldt (*Spheniscus humboldti*) et les Manchots de Magellan (*S. magellanicus*) nichent de façon sympatrique sur les îlots Puñihuil, deux petites îles au large de la côte ouest de l'île de Chiloé (41° S.) qui font l'objet de visites touristiques dans le sud du Chili. L'objectif de notre étude était de comparer la taille des deux populations de manchots avant et après l'établissement d'une réglementation touchant le tourisme et les chèvres en liberté en 1997. À cette fin, deux relevés ont été effectués en 2004 et 2008, et les résultats ont été comparés à ceux obtenus en 1997 par d'autres auteurs. La proportion de terriers occupés, non occupés ou effondrés/inondés a varié selon les années; ainsi, il y a eu 68 % et 34 % moins de terriers effondrés en 2004 et 2008, respectivement, qu'en 1997. Pour ce qui est du nombre de terriers des deux espèces, nous avons compté 48 % et 63 % plus de terriers en 2004 et 2008, respectivement, qu'en 1997. Nous avons compté 13 % plus de terriers de Manchots de Humboldt en 2008 par rapport à 1997, et avons observé une hausse de 64 % pour les terriers de Manchots de Magellan en 2008. Nous pouvons présumer que ces hausses résultent de l'amélioration de l'habitat consécutive à l'exclusion des touristes et au retrait des chèvres des îlots. Même si les visites touristiques sont maintenant interdites sur les îlots, l'activité touristique aux abords des colonies a toujours cours et doit être prise en compte si on veut mettre en place une gestion adéquate.

Key Words: *burrow activity; exclusion; protected area; Spheniscus humboldti; Spheniscus magellanicus; tourism*

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INTRODUCTION

Historically, marine protected areas (MPAs) have been designated worldwide to protect marine resources, through fisheries management, habitat protection, and conservation of biodiversity (Boersma and Parrish 1999, Hooker and Gerber 2004). This includes top predators such as seabirds, one of the most important indicators of many aspects of the functioning of marine systems at regional and global scales and one of the most threatened groups of birds. At sea, the principal threats are pollution and interaction with fisheries, whereas on land these threats are constituted of alien invasive predators, habitat degradation, and human disturbance (Croxall et al. 2012). It has been suggested that MPAs benefit seabirds, allowing them to improve foraging effort (Louzao et al. 2006, Pichegru et al. 2010) and increasing breeding productivity (Frederiksen et al. 2008). Although the population trends of terrestrial birds have a positive correlation with protected habitats (Donald et al. 2007), there is no conclusive information on whether protected areas can improve population trends of seabirds when these areas are further exploited as tourist attractions. Tourism activities associated with seabird breeding colonies have been developed in several regions and have increased in past decades (Yorio et al. 2001*a*). Tourism can result in disturbance to birds when the tourism activity is not controlled or is poorly managed (Carney and Sydeman 1999). These effects include reduced breeding success (Beale and Monaghan 2005), changes in nest distribution patterns (Anderson 1988, Hill and Rosier 1989), size trends in the breeding population (Barnes and Hill 1989), nest predation (Devney and Congdon 2009), loss or deterioration of habitat (Oro 2003, Martínez-Abraín et al. 2004), reduction in foraging activity and exclusion of birds from foraging areas (Velando and Munilla 2011), and changes in behavior (Anderson and Keith 1980, Burger and Gochfeld 1993). Thus, to ensure positive effects, MPAs require that the regulations exclude or restrict human activities that impact negatively on the resource (Frederiksen et al. 2008).

Spheniscus penguin colonies, in particular, are popular tourist destinations in Argentina and Chile (Simeone and Schlatter 1998, Skewgar et al. 2009, Villanueva et al. 2012). Negative effects such as reduced breeding success, lower fledging weights, changes in normal behavior, higher heart rates, lower nest densities, collapsed burrows, and higher levels of stress-induced hormones in penguins in frequently visited sites have been observed for various penguin species (Villanueva et al. 2012). The effect of tourist disturbance can vary from one species to another as in the Humboldt Penguin (*Spheniscus humboldti*) and Magellanic Penguin (*S. magellanicus*) because Humboldt Penguins are shier and more sensitive to human presence than Magellanic Penguins (Ellenberg et al. 2006). This is because Humboldt Penguins have been hunted by coastal human communities in northern Chile and Peru for more than 11,000 years, whereas Magellanic Penguins in the sparsely populated southern and eastern coasts of South America have never experienced selection pressure of a similar magnitude (Ellenberg et al. 2006 and references therein). Therefore, the effect of protecting areas in mixed-species colonies under exploitation by tourists may exert different responses in these penguin populations.

For *Spheniscus* species, three mixed colonies are known, with the largest reported at Puñihuil Islets, two small coastal islands off the west coast of Chiloé Island (41° S) in southern Chile (Duffy 1987, Wilson et al. 1995, Simeone and Schlatter 1998). The biological relevance of this Humboldt/Magellanic Penguin colony was recognized by its potential for species hybridization, allowing studies of resource partitioning, behavioral interactions, diet comparisons, foraging ecology, and habitat use (Wilson et al. 1995, Simeone and Schlatter 1998, Raya Rey et al. 2013). At the time of its discovery in 1985, no threats were evident for this unique colony, and the site was not officially protected (Duffy 1987).

More than a decade after its discovery, the mixed-species population at Puñihuil was estimated at 561 adult Magellanic and 210 adult Humboldt Penguins. There was serious damage to the nesting burrows from trampling by goats introduced in 1988 and unregulated tourism (Simeone and Schlatter 1998). Trampling and overgrazing by goats alters the structure and composition of plant communities, causing habitat degradation and accelerating soil erosion (McChesney and Tershy 1998, Campbell and Donlan 2005 and references therein), which results in the collapse of breeding burrows of seabirds. In addition to this problem, and according to the local residents, mostly fishermen, these islands are the most accessible known places in Chile where the two penguin species breed, making this a very popular tourist attraction in Chiloé. This has resulted in an unknown number of people visiting the colonies while no regulations or management plans were in place. Regarding their conservation on the Pacific coast, populations of both species have been decreasing as a result of entanglement in artisanal fishing nets and illegal capture for consumption and bait (Simeone et al. 1999, Majluf et al. 2002, Pütz et al. 2011). In Argentina, human disturbance by tourism has been described as one of the main threats to the breeding colonies (Boersma 2009). As a result, the conservation status of these species is classified by Bird Life International as vulnerable for Humboldt Penguins (http://birdlife.org/datazone/speciesfactsheet.php?id=3862) and near threatened for Magellanic Penguins (http://birdlife.org/datazone/speciesfactsheet.php?id=3863). There is no information about population trends in the areas where the species occur in sympatry.

In 1999, the colonies became officially protected by the Chilean Forest Service (CONAF). The islets became a "Natural Monument," subject to some regulations of MPAs (Guarderas et al. 2008). Access to the penguin colony was forbidden as a main restriction, and all the resident goats, of which there were at least six, were removed (Simeone and Schlatter 1998); however, tourist activities continued to occur around the islets through boat trips. Protection was reinforced by a nongovernmental organization, which provided constant surveillance and environmental education to locals. Following these conservation measures, the penguin population was expected to increase in numbers, but differentially between the species, with a greater increase for Magellanic Penguins, the less sensitive and less shy species. Our aim was to verify this expectation and accurately estimate the population sizes of both penguin species on the islets.

METHODS

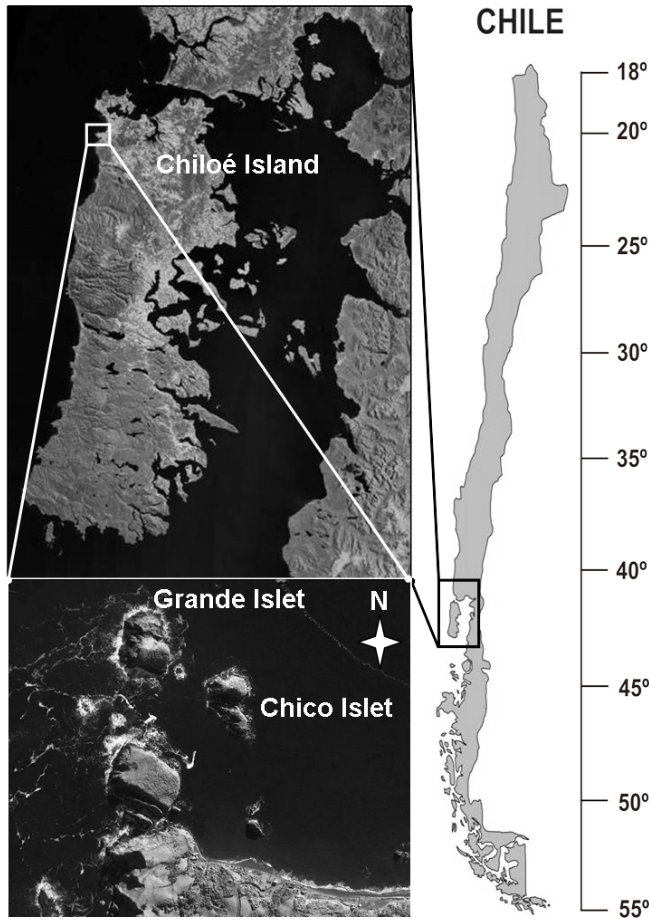
Study area

The Puñihuil Islets lie in the exposed Pacific Ocean off the Isla Grande de Chiloé (41°55′ S, 74°02′ W). Chico Islet and Grande Islet have areas of 1.54 and 2.65 ha, respectively, and are located 340 m and 700 m offshore, respectively (Fig. 1). Vegetation is composed mostly of understory bamboo (*Chusquea* sp.), the bromeliads *Fascicularia bicolor* and *Greigia sphacelata*, which are in the central part of the islets, and herbaceous vegetation such as *Holcus lanatus* and *Anthoxantum odoratum* (Simeone and Schlatter 1998). We omitted the largest third islet known as Huiguape (4.45 ha) because of its inaccessibility. Today, there is intense tourist activity from guided boat tours around the islets, mainly during the austral spring and summer (Skewgar et al. 2009). Access ashore to the islets is still forbidden under the Natural Monument regulations. Chico Islet was the only islet with a population of goats until their removal in 1999 (Simeone and Schlatter 1998).

Nest census

We conducted a complete nest census on both islets from 6 December to 8 December 2004 and again from 20 November to 30 November 2008, when the breeding activities of both species had already begun. At the time of the counts, the contents of the nests of both species ranged from incubating eggs to one to two chicks of up to five weeks, thus ensuring the distinction between an occupied and an unoccupied burrow. The counts were conducted between 1000 and 1600 local time following the methods described by Simeone and Schlatter (1998) from 26 February to 27 February 1997 at the same islets. Because both species were very sensitive to the presence of investigators (Fowler 1999), we counted and checked burrows only once, dividing the total area of every islet into smaller plots distinguished by topographic or vegetation marks and making transects inside to avoid double counting. We inspected each burrow, and its content was assigned to one of three categories according to its activity: (1) occupied burrows, those containing at least one adult with or without eggs, chicks, or their combinations; (2) unoccupied burrows, those with no adults inside and that were empty; and (3) flooded/collapsed burrows or those containing abandoned eggs that were outside of the nest. Because we were interested in the impact over all breeding stages of penguins, we did not distinguish between burrows with breeding pairs and burrows with single penguins. It is important to note that the latter were represented by 4.2% and 3.3% of the total burrow counts in 2008 in Chico and Grande Islets, respectively.

Fig. 1. Map of the Puñihuil Islets, Chiloé, Chile, showing the location of the mixed colony of penguins in Chico Islet and Grande Islet.



In 2004, nests were additionally categorized according to the substrate as (1) burrow constructed in soil, (2) rocky burrow, or (3) burrow in soil covered by vegetation. We also recorded the nest condition: collapsed or intact. Counts of collapsed burrows allowed the evaluation of the impact of goat removal. We conducted nest inspections with a flashlight and occasionally used a pole to move the bird carefully and determine nest contents. The examination of the burrow usually took a few seconds; thus, damage to the nest and its occupants was minimized.

Table 1. Observed frequencies, chi-square test, and p-values for 2 × 3 contingency tables (df = 2) for 1997-2004 and 2004-2008 reveal changes in the proportion of occupied, unoccupied, and collapsed burrows between the census of the mixed colony of penguins in Puñihuil Islets, Chiloé, Chile. Percentages were calculated based on data from 1997. Proportions of all burrows counted for particular years and islets are indicated in parentheses. Significant values are highlighted by an asterisk (*). Data for 1997 was taken from Simeone and Schlatter (1998).

	Occupied	%	Unoccupied	%	Collapsed	%	Total	%	χ^2	p
Chico Islet										
1997	131(46)	–	96(34)	–	58(20)	–	285(100)	–		
2004	198(54)	+51	159(43)	+66	9(3)	-84	366(100)	+28	55.83	< 0.01*
2008	238(52)	+82	202(44)	+110	17(4)	-71	457(100)	+60	1.21	0.55
Grande Islet										
1997	235(44)	–	254(48)	–	40(8)	–	529(100)	–		
2004	369(44)	+57	450(53)	+77	22(3)	-45	841(100)	+59	19.48	< 0.01*
2008	348(40)	+48	474(54)	+87	48(6)	+20	870(100)	+64	10.41	< 0.01*
Both Islets										
1997	366(45)	–	350(43)	–	98(12)	–	814(100)	–		
2004	567(47)	+55	609(50)	+74	31(3)	-68	1207(100)	+48	74.44	< 0.01*
2008	586(44)	+60	676(51)	+93	65(5)	-34	1327(100)	+63	10.19	0.01*

In 2004 and 2008, we were only able to survey 90% of the total area on Grande Islet because there was an inaccessible dense cover of understory bamboo in the core zone of this islet, i.e., the same scenario as in 1997, resulting in an underestimation of the number of burrows beneath this zone. We compared the proportion of occupied, unoccupied, and collapsed/flooded burrows between 1997, 2004, and 2008.

Statistics

We used contingency tables with the chi-square test to determine changes in the proportion of burrow count frequencies in different years. To determine changes in the proportion of occupied, unoccupied, and collapsed/flooded burrows, we used a 2 × 3 contingency table, and to determine changes in the proportion of species, we used a 2 × 2 contingency table, excluding hybrids and chicks alone, between 1997 and 2004 and between 2004 and 2008. To determine if the proportion of the substrate used by penguins changed between 1997 and 2004, we used a 2 × 4 contingency table for the observed frequencies of occupied, unoccupied, and collapsed/flooded Humboldt and Magellanic Penguin burrows.

RESULTS

Changes in the number of burrows

The total number of Magellanic and Humboldt Penguin burrows increased significantly on both islands (Table 1). Compared with 1997, the numbers increased by 48% and 63% in 2004 and 2008, respectively. With regard to individual islets, 28% and 60% more burrows were counted on Chico Islet, and 59% and 64% more burrows were counted on Grande Islet (Table 1).

The total number of occupied burrows also increased compared with 1997 levels; we estimated an increase of 55% and 60% in 2004 and 2008, respectively. On Chico Islet, we counted 51% and 82% more burrows for the same time period, and on Grande Islet, the increase was 57% and 48%, respectively (Table 1).

We counted 74% and 93% more unoccupied burrows in 2004 and 2008 compared with 1997. For Chico Islet, the increase was 66% and 110% for the same time period, and for Grande Islet, the increase was 77% and 87%, respectively (Table 1).

Collapsed burrows

The total number of collapsed burrows on both islets decreased by 68% and 34% in 2004 and 2008, respectively, compared with 1997. However, although in 2008 this decrease reached 71% on Chico Islet, the number of collapsed burrows increased by 20% on Grande Islet (Table 1).

Magellanic and Humboldt Penguins after tourist/visitor exclusion and removal of goats

The relative proportion of burrows of the species changed only between 1997 and 2004 on Grande Islet (Table 2). The Magellanic:Humboldt ratio was 4:1, 5:1, and 4:1 in 1997, 2004, and 2008, respectively, on Chico Islet; whereas the ratio on Grande Islet was 4:1 in 1997 and 7:1 in the following years.

Overall, we counted 13% more burrows of Humboldt Penguins in 2008 than in 1997. On Chico and Grande Islets, we estimated 59% more and 12% fewer burrows, respectively, for the same time period (Table 2). For the Magellanic Penguin, we estimated an increase of 64% in burrows in 2008. This increase reached 78% and 57% on Chico Islet and Grande Islet, respectively. Moreover, for both islets in 2008 we

Table 2. Observed frequencies, chi-square test, and p-values for 2 × 2 contingency tables (df = 1) for 1997-2004 and 2004-2008 reveal changes in the proportion and increase in number of burrows through the years for Humboldt Penguin (HuPe; *Spheniscus humboldti*) and Magellanic Penguin (MaPe; *Spheniscus magellanicus*) in Puñihuil Islets, Chiloé, Chile. Percentages were calculated based on data from 1997. Proportions from all burrows counted for particular years and islets are indicated in parentheses. Significant values are highlighted by an asterisk (*). Data for 1997 was taken from Simeone and Schlatter (1998).

	HuPe	%	MaPe	%	Hybrids / chicks alone	%	Total	%	χ^2	p
Chico Islet										
1997	27(9)	–	104(37)	–	–		131(46)	–		
2004	30(8)	+11	151(41)	+45	17(5)	–	198(54)	+51	0.83	0.36
2008	43(9)	+59	185(41)	+78	10(2)	-41	238(52)	+82	0.36	0.55
Grande Islet										
1997	49(9)	–	186(35)	–	–		235(44)	–		
2004	46(5)	-6	307(37)	+65	16(2)	–	369(44)	+57	6.37	0.01*
2008	43(5)	-12	292(33)	+57	13(2)	-19	348(40)	+48	0.01	0.94
Both Islets										
1997	76(9)	–	290(36)	–			366(45)	–		
2004	76(6)	0	458(38)	+58	33(3)	–	567(47)	+55	6.60	0.01*
2008	86(6)	+13	477(36)	+64	23(2)	-30	586(44)	+60	0.24	0.63

recorded 30% fewer burrows with chicks alone and hybrids than in 2004 (Table 2).

Nest characteristics

In the 1997 and 2004 censuses, both penguin species mainly nested in soil, followed by burrows under bamboo and occasionally under bromeliads (Table 3). For occupied burrows, the proportion of use in the substrate changed significantly on Grande Islet with an increase of the bamboo substrate (χ^2 = 11.76, p = < 0.01; Table 3), particularly for Magellanic Penguin burrows. On Chico Islet, the proportion of burrows by type of substrate changed significantly for the number of empty soil burrows (χ^2 = 21.69; p = < 0.01), with an increase of 157%; whereas the number of collapsed/flooded soil burrows decreased by 287% in 2004 and 241% in 2008. Similarly, on Grande Islet, empty soil burrows increased by 52%, and collapsed/flooded burrows increased by 22% in 2004 and by 20% in 2008 compared with 1997 (Table 3).

DISCUSSION

Ecotourism, especially wildlife observation, has been a rapidly growing activity and has resulted in specifically designed activities with benefits to local and regional people and agencies. However, it has been acknowledged that visitation by people interested in the conservation of wildlife can have severe impacts on the wildlife itself (e.g., Boyle and Sampson 1985, Otley 2005). Colonial nesting seabirds are particularly vulnerable to disturbances (Carney and Sydeman 1999), and many wildlife-watching guidelines have been established, with varying success. We report on the recovery of a mixed colony of Humboldt and Magellanic Penguins at Puñihuil Islets, central Chile, following the establishment of guidelines and the removal of alien species from the habitat.

The increase in the total number of burrows after 1997 was assumed to be a direct consequence of the regulations imposed at that time. Compared with 1997, nest numbers for the entire mixed colony for 2004 and 2008 revealed that the increase in number of burrows was more pronounced, but in relative proportions similar, in Magellanic compared with Humboldt Penguins. Significant changes in the proportion of burrows between 1997 and 2004 in favor of Magellanic Penguins may reflect a faster recovery of this species after the regulations became established. This was supported by the fact that the proportion remained similar between 2004 and 2008, thus reflecting a balance in the breeding numbers of the penguin species compared with the numbers without human disturbance and goats. Ellenberg et al. (2006) reported that Humboldt Penguins are more affected by human disturbance than any other penguin species. In addition, Humboldt Penguins are smaller and arrive two to three weeks later in the colony than Magellanic Penguins (Simeone and Schlatter 1998) and are thus restricted in their nest site choices. Despite these disclaimers, it is evident that in species with a critical conservation status, smaller populations and life history affected by human disturbances, as in the case of Humboldt Penguins, the application of conservation measures is a useful tool to enhance their population status.

The magnitude of the total increase in breeding pair numbers was certainly a direct consequence of the conservation measures implied, but other factors may also have contributed to the observed increase. For example, the timing of the censuses has been different. The 1997 study, done almost three months later in the breeding season, included those occupied burrows containing molting adults and not necessarily all breeders, but it also excluded failed breeding attempts of birds

Table 3. Observed frequencies, chi-square test, and p-values for 2 × 4 contingency tables (df = 3) reveal changes in the proportion of use in the substrate between censuses of burrows of penguins in 1997 and 2004 for occupied and unoccupied burrows in Puñihuil Islets, Chiloé, Chile. Significant values are highlighted by an asterisk (*). Humboldt penguin (HuPe; *Spheniscus humboldti*), Magellanic penguin (MaPe; *Spheniscus magellanicus*).

	HuPe		MaPe		Occupied (HuPe + MaPe)		Unoccupied		Collapsed	
	1997	2004	1997	2004	1997	2004	1997	2004	1997	2004
Chico Islet										
Soil	21	27	76	123	97	150	51	131	58	15
Bamboo	0	0	5	8	5	8	5	3	0	0
Bromeliads	3	1	23	20	26	21	36	34	0	0
Rock	3	2	0	0	3	2	4	0	0	0
χ^2; p-value	1.79; 0.62		3.46; 0.33		4.91; 0.18		21.69; < 0.01*		0; 1	
Grande Islet										
Soil	38	27	125	171	163	198	178	271	40	49
Bamboo	11	19	61	133	72	152	67	136	0	2
Bromeliads	0	0	0	3	0	3	9	14	0	0
Rock	0	0	0	0	0	0	0	0	0	0
χ^2; p-value	3.90; 027		7.63; 0.05		11.76; < 0.01*		2.65; 0.45		1.60; 0.66	

that lost their eggs or chicks earlier in the season. However, these two factors positively and negatively influenced our results, and it thus appears that tourist exclusion and goat removal resulted at first in a significant increase in burrow numbers for both species in both colonies between 1997 and 2004, whereas this trend stabilized afterward.

There are a few examples supporting a positive relationship between seabird populations and the establishment of MPAs. For example, in the African Penguin (*S. demersus*), the foraging effort decreased after the establishment of an MPA (Pichegru et al. 2010). Other examples include the enhancement of breeding distribution in the Black-footed Albatross (*Phoebastria nigripes*; Hyrenbach et al. 2006), a population increase in the Kelp Gull (*Larus dominicanus*; Yorio et al. 1998), the protection of breeding adults in Giant Petrels (*Macronectes* sp.; Trebilco et al. 2008), and improvements of other aspects of life history, reviewed for marine megafauna by Hooker and Gerber (2004). We have demonstrated that the establishment of an MPA in a seabird colony perturbed by unregulated tourism and introduced goats resulted in an increase in the populations of two penguin species and presumably other seabird species breeding on the islets, e.g., the Red-legged Cormorant (*Phalacrocorax gaimardi*) and the Kelp Gull.

Further conservation measures

So far, the long-term impact of regulated tourism on penguin populations has not yet been sufficiently established, mainly because of the lack of population trends described for other *Spheniscus* colonies in South America exposed to tourism. However, the increasing number of unoccupied burrows after 1997 may mirror the dynamics between regulated tourism activity and penguin life history. In general, unoccupied burrows may be a result of nest desertion earlier in the breeding season (Yorio et al. 2001*a*), but on the other hand, they offer the potential of reoccupancy by penguin recruits in the years to come. Skewgar et al. (2009) acknowledged a report from 2007 in which it was considered that current tourist visitations and logistics appeared sustainable; however, at the same time, the biological impacts of tourist numbers on penguin behavior and ecology were not considered. Taking into account that *Spheniscus* species have high intraspecific breeding synchrony (e.g., *S. magellanicus*, Yorio et al. 2001*b*; *S. demersus*, Wolfaardt et al. 2009), the number of unoccupied burrows is unlikely to be a result of temporal differences in the rate of occupancy of breeding burrows used by the penguins. Although there are other factors that may influence population trends in the long term, penguins in general have evolved to cope with oceanographic dynamics that define spatial-temporal variability of resources in the area, e.g., African Penguins (Pichegru et al. 2010). The natural scenario occurs when major events affecting resource availability, such as the El Niño Southern Oscillation, are absent. Therefore, we presume that the current penguin population trends may mirror the impact of ecotourism activities on this mixed-species colony. Although regulations imposed in 1997 have had a measurable effect on breeding pair numbers on the Puñihuil Islets, some threats still remain. To further increase the protection of the islets and their inhabitants, we propose the establishment of the following measures, in line with Skewgar et al. (2009):

1. Reduce the number of tourists. An increase in the number of visitors to the islets may cause a decrease in breeding success or long-term physiological changes in penguins

(Fowler 1999, Trathan et al. 2008, Lynch et al. 2010). In Puñihuil the number of visitors on touristic boats reached a total of 7000 in 2004 and increased to 20,000 in 2009 (Skewgar et al. 2009).

2. Implement ecotourism management. Up until 2010, tourism increased without the application of concurrent control measures, which implies that activities disturbing the colony, such as unregulated touristic boat presence, may also have increased before this date.

3. Control pollution increases. As tourism continues to increase, pollution affecting the marine ecosystem will also increase (Hardiman and Burgin 2010, Braun et al. 2012).

4. Reduce the mortality of penguins in gill nets. Records indicate that 50 penguins drowned in 2006 (Skewgar et al. 2009) because of a group of Chilean croaker (*Cilus gilberti*) gill netters who were not participating in ecotourism.

Collapsed burrows

Our data revealed a reduced number of collapsed burrows after nearly eight years of protection of the islets. This is mainly because of the removal of goats from Chico Islet (Simeone and Schlatter 1998). Obviously, islet protection has stimulated penguins to re-excavate collapsed burrows or to build new ones in sites previously affected by trampling. For the different types of substrate, the decrease in collapsed burrows and increase in burrows for both penguin species and for unoccupied burrows was greatest in the soil, mirroring more use of this type of substrate than vegetal or rock substrates because the proportions of the number of burrows in these habitats did not change between 1997 and 2004. Furthermore, collapsed burrows occurred only in the soil in 1997, probably because of the inaccessibility of dense vegetation to goats.

For the mixed-species colony at Puñihuil, the number of collapsed burrows on Grande Islet after 1997 and on both islands after 2004 may be considered as natural burrow collapse, which can result from intense rainfall in the area or from trampling by penguins (Simeone and Schlatter 1998) because goats were not introduced on this islet. These effects can be seen more clearly on Grande Islet where the soil was eroded in the absence of vegetation in a large part of the islet. The tourism activity could have influenced the proportion of occupied burrows between 1997 and 2004, when the increase in burrow numbers was greater in bamboo substrate than in soil, particularly for Magellanic Penguins. Soil burrows were located closer to the coast and were more exposed to boat presence than burrows in the bamboo because this type of substrate was located in the high central part of the islet, away from the coast. This is particularly marked in Humboldt Penguins, for which burrows decreased in soil substrate and increased in the bamboo habitat. Chatwin et al. (2013) reported that boat traffic can have severe effects on breeding or roosting seabirds. Despite some habituation responses, they recommend a minimum distance of 50 m for boats and kayaks around the coastline of sites used for ecotourism.

Additionally, the improved quality of the penguin nesting habitat is relevant because the quality of a site has a direct effect on current and future pair breeding success (Knight and Rogers 2004, Descamps et al. 2009). If the burrow has collapsed or flooded after the breeding season, the chance of mate fidelity will be reduced because fidelity is influenced by the ability to meet again at the nest in the following season (Yorio and Boersma 1994, Knight and Rogers 2004). Secondly, if the current breeding success is low, e.g., burrow collapse by trampling, the probability of pair divorce will be high (Dubois and Cézilly 2002, Setiawan et al. 2005).

Conservation and management

The penguin and seabird colonies at Puñihuil are attracting a significant number of ecotourists, with locals benefiting from this activity, e.g., fishing syndicates and private tour operators (Skewgar et al. 2009). The current activities at Puñihuil appear to be in line with good practices, i.e., those developed in a context of responsibility toward the environment, for the penguin colonies (but see Chatwin et al. 2013); however, there is a need to continue assessing the population trends of penguins and other seabirds. In addition, it is important to consider environmental variables that can affect penguin populations to discriminate between human and natural effects. Despite some regulations, like the local county ordinance that has regulated tourism activity around the islets in Puñihuil since 2009, human activities near the colonies are likely to constitute a source of behavioral and physiological stress for the penguins (Walker et al. 2005, 2008, Ellenberg et al. 2007, Chatwin et al. 2013). These perturbations could be reduced by limiting activities to certain areas of the colonies where birds could habituate to human presence (Fowler 1999). Nevertheless, this management must consider the susceptibility of the birds at critical stages, i.e., incubation and molt, when the energy stores of birds are low and any extra costs may influence their survival rates (Hood et al. 1998). Examples of negative impacts on seabird colonies attributable to poorly managed tourism are abundant (see Carney and Sydeman 1999 for a review), but there are also examples of sustainable coexistence between tourism and seabird conservation, particularly in penguin colonies (e.g., Boersma and Stokes 1995, Holmes 2007, Landau and Splettstoesser 2007, Powell et al. 2008). In this context, the effects of regulations like the ordinance that improved the management of tourism in Puñihuil will be reflected in the penguin populations in the middle and long term.

The second conservation challenge in protected penguin colonies is that protection must be compatible with research activities where the uniqueness of these colonies makes them highly attractive to studies of comparative ecology and potential interactions between the two species of penguins. Indeed, the development of scientific research can be of great value to tourism because the knowledge generated in the colonies could improve the quality of information for visitors, producing a "value-added" experience for tourists if traveling with expert guides. Moreover, the likelihood of success of management plans would also increase with the involvement of representatives from government, private, academic, and nongovernmental organizations. Therefore, after the establishment of a protected area, there is also a need to improve the management of habitats, both animal and human inhabitants, and habits, especially of humans; the latter is a crucial part of conservation planning.

Responses to this article can be read online at:
http://www.ace-eco.org/issues/responses.php/617

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