Title
Considerations for Creating a Marine Protected Area for *Spheniscus* Penguins in Southern Chile

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CONSIDERATIONS FOR CREATING A MARINE PROTECTED AREA FOR SPHENISCUS PENGUINS IN SOUTHERN CHILE

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Capstone Project

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ABSTRACT

Marine Protected Areas (MPAs) are gaining wide support as a management and conservation mechanism. MPAs target everything from a single species to an entire ecosystem and although success in achieving desired management goals varies on a case-by-case basis, their implementation has significantly changed management paradigms for the better. In southern Chile, Puñihuil Islets (42ºS) contain the largest described mixed-species colonies of *Spheniscus* penguins. Humboldt (*Spheniscus humboldti*) and Magellanic (*S. magellanicus*) penguins breed here sympatrically and provide an unprecedented opportunity to understand the ecological context, which allows for successful resource partitioning between these closely related species. This region is also economically important for fisheries, such as Chilean abalone, mussel and corvine, as well as for ecotourism. Because bycatch in the coastal gillnet fishery has historically been described during the breeding season, with 50 penguins drowning in 2006 and one penguin drowning registered by a time-depth recorder in 2008, we propose a framework for establishing an MPA based on the biology of the penguins. During chick rearing, foraging behavior based on 12 Humboldt and 10 Magellanic penguins tagged with GPS TD loggers indicates that the birds occupied an area at-sea up to 106 km^2. After moulting, between April and August it has been described that certain individuals disperse over a coastal area ranging from the breeding site 1000 km to the north and return to the colony for breeding activities. We therefore recommend a time-sensitive MPA whereby coastal gillnets are not allowed to fish in this area during this time. We further provide diverse MPA options where boundaries and sizes were created based on the utilization areas at-sea during early chick rearing.

Key words: *Spheniscus* penguins, gillnets, GPD TD loggers, MPAs

INTRODUCTION

The intensity of human activities on marine resources has resulted in that significant numbers of marine organisms are now categorized as threatened or endangered. Habitat damage and loss of species are attributable to unregulated or poor management human actions. Undoubtedly, new management approaches or options are needed to restore damage and ensure stability in marine ecosystems. In order to minimize the burgeoning influence of human-use on marine ecosystems, the creation of Marine Protected Areas (MPAs) has been proposed as management tool to secure the long-term sustainability of marine environments (Allison et al 1998, Worn et al 2006, Rogers and Laffolley 2011, Ludynia et al., 2012). In that context, MPAs are crucial to re-establish ecosystem integrity, targeting everything from a single specie to an entire ecosystem (Allison et al., 2003, Micheli et al., 2008) and although success in achieving desired management goals varies on a case-by-case basis, their implementation has significantly changed management paradigms for the better. Although the variety of benefits that MPAs provide to marine ecosystems are well recognized, less than 1.5% of the global ocean are under any form of protected designation (Spalding et al., 2010), despite the international agreement of 10% of the ocean to be protected by 2020 throughout a network of MPAs (Toropova et al., 2010).

Top predators play crucial roles in the dynamic and stability of marine ecosystems, yet their protection has receive little attention. Considering that their populations are declining world wide due to a combination of anthropogenic disruption, such as mortality from fishing gear (Tasker et al., 2000), and changes in the stability of marine ecosystems, the establishment of MPAs appears to be the appropriate tool to remediate these effects. For instance, diverse tools have been proposed for protecting seabirds during the breeding season, as well at their foraging areas (see European

Commission, 2007). Throughout reproductive stages, protection of seabirds is becoming increasingly important for the establishment of protected foraging areas that may be crucial for breeding success (e.g., Hooker et al 2006).

Although diverse components are needed for designing and implementing an MPA for seabirds, the following three are recognized to be the most important: the status (abundance, distribution, and trends) of the target species; type and intensity of human interaction with seabirds; and how these activities are likely to affect seabirds. Such evidence should make it possible to evaluate the conservation benefits of establishing an MPA, as well to provide the size and boundaries required (Lascelles et al., 2012). Foraging ranges of breeding seabirds provide a well-defined tool for the initial assessment of candidate MPAs. For example, boundaries designed for a fishery exclusion zone in South Africa were determined based on penguin foraging range (Pichegru et al., 2010).

In Chile, most of the existing protected areas were created in response to the high abundance or diversity of seabirds and marine mammals (Tognelli et al., 2009). However the size and boundaries designated do not appear to be adequate for the effective protection of some species. Considering that seabirds are widely dispersed organisms that often feed on highly mobile prey, and potentially cover vast areas at sea throughout the annual cycle, especially during the non-breeding dispersal stage. Even during the breeding season, some species frequently cover large areas of several hundred kilometers. For instance, Magellanic penguins (*Spheniscus magellanicus*) at Punta Tombo were described to forage hundreds of kilometers far from the colony during incubation and chick rearing (Stoke and Boersma 1999).

Humboldt Penguin (*S. humboldti*) and Magellanic Penguin occur along the coast of Chile, and one of the major trends that these birds had experienced, are related with interaction with fishing gear, particularly gillnets. In particular, the interaction with coastal gillnets has been recognized as one of the major anthropogenic disturbances for both species of penguins in Chile (e.g., Schlatter et al 2009, Pütz et al 2011). From 2005 to 2010, at least 5,000 penguins have been founded entangled and drowned by the effects of coastal gillnet fisheries (A.S. pers. comm.). Populations of Humboldt and Magellanic penguins are in decline, and are listed as "Vulnerable" and "Near threatened", respectively, according to the IUCN Red List criteria (IUCN 2012). These declines have been related to El Niño events (Luna-Jorquera 1996), as well interaction with coastal gillnets and pollution (Simeone and Schlatter 1998, Boersma 2008).

This paper focused on identifying boundaries for creating an MPA during the breeding season of Humboldt and Magellanic penguins in southern Chile, in order to mitigate the impact of gillnets. We used GPS TD loggers technology to identify the foraging areas for both species in Puñihuil islets, northern Chiloe Island. Therefore, we present information on the foraging areas and ranges during the breeding season of 2008-2009 and how these datasets provide the size and boundaries required to design an MPA during the penguins breeding season.

METHODS

Study Area

The three islets of Puñihuil are located along the west coast of Chiloe Island in southern Chile (Fig. 1). They support the largest mixed-species colony of *Spheniscus* penguins in the world (Simeon and Schlatter 1998, Simeone 2004). The region is well known as a hotspot for marine biodiversity due to the highly productive waters (e.g., Camus 2001) and is critical area for breeding seabirds on Chiloe Island (Simeone and Schlatter 1998). Because the islets serve as a link for migratory species, such as

Humboldt and Magellanic penguins, they were declared a "Natural Monument" in 1999, administered by the Chilean National Forest Service (CONAF). The total protected (i.e., no human access allowed) surface is 8.64 ha. (Simeone and Schlatter 1998).

Identifying temporal boundaries of the proposed closure within the MPA

We compiled data on Humboldt and Magellanic penguin population size on the islets from existing literature. Nest censuses were conducted during 26-27 of February 1997 (Simeone and Schlatter 1998), 6-8 of December 2004 and 20-30 of November 2008 (Simeone 2004, Reyes Arriagada et al in prep.). The censuses were conducted between 10:00 and 16:00 hrs. (GTM -4) and each burrow was individually checked and recorded its contents determined (adult individuals of each species, hybrids, eggs and/or chicks: Reyes Arriagada et al in prep.).

Identify the spatial boundaries of the proposed MPA

In 2008, during the early-rearing stage, we conducted a tracking study to document the foraging ranges of the sympatric population of Humboldt and Magellanic penguins (see Raya Rey et al unpubl. data). These tracking data represent the only study of foraging behaviour of this mixed-colony available.

From 11 of November to 15 of December, both species were tracked using global positioning system with pressure sensor devices (GPS, GPS-TDlog, Earth & OCEAN Technologies, Kiel, Germany). Attachment of the loggers took less than 20 minutes. Briefly, we captured adult birds that were attending chicks from 1-15 days old. Adults were carefully removed from their burrows by hand. Loggers were attached along the midline of the back as far as distally possible without impairing the preen gland, using black tape (Tesa, Beiersdorf AG, Hamburg, Germany) according to Wilson et al. (1997).

Each device was covered with a layer of epoxy (Loctite® 3430, Loctite Deutschland GmbH, München, Germany). Each GPS TD logger measured 96*39*27 mm, corresponding to ~ 6.5% of the cross sectional area of the study birds, and a total of 75 g corresponding to *ca.* 1.7% of the mean Magellanic Penguin body mass. GPS's were successfully deployed on 12 Humboldt and 10 Magellanic penguins for between 1 and 3 days per bird. This represents 36 successfully tracked from both species over 33 days.

In order to identify zones of high occupancy and to obtain the utilization area from both species, we conducted a kernel density analysis from the density function in the spatial analysis extension in ArcGIS 10.0. We analyzed 18 trips for Humboldt and 18 trips for Magellanic penguins. Utilization areas were derived from kernel and separated into 3 percentile regions, where penguins likely to spend, corresponding to 50, 75 and 95%. The overlap analysis of kernel contours and the polygons plotted were made using tools in ArcGIS 10.0. Based on the foraging range of both nominate species, an initial set of MPAs boundaries was determined by drawing perimeters to delineate a protected area off Puñihuil islets. These distribution patterns were taken as a baseline for the designing proposal MPA outline.

RESULTS

Temporal boundaries of the MPA

Both species initiate their breeding season from August to March every year in the area (see Fig. 2). Since 1999, when the islets were declared 'Natural Monument", the number of pairs has been gradually increasing. Between 1997 and 2004 the total number of burrows at Puñihuil increased from 814 to 1207, a total increase of 393 (48%); between 2004 and 2008 there was a further increase of 120 (10%) burrows. The number of penguins (both species) occupying burrows increased from 366 to 567, a total increase of 201 (55%) from 1997 to 2004, and another 19 (3%) from 2004 to 2008. Burrows occupied by Humboldt penguins experienced no fluctuations between 1997 and 2004, and increased from 76 to 86 (13%) from 2004 to 2008 respectively. Magellanic penguins also showed an increase from 290 to 458 (58%) between 1997 and 2004, and an additional 19 burrows from 2004 to 2008 (Fig. 3). Magellanic penguins were more abundant than Humboldt penguins, by a ratio of 5:1 (Simeone et al 2004, Reyes Arriagada et al unpubl. data).

Spatial Area At-sea

Data obtained by using GPS TD loggers on Humboldt and Magellanic penguin during the breeding season of 2008-2009 were used to identify the spatial area at sea. The foraging range extended a maximum distance from the colony of 15 km. While both nominate species used areas to the north and south off the islets, Humboldt penguins more frequently made northern trips, while Magellanic penguins experienced southern area off the Puñihuil (Fig. 4). From 12 Humboldt penguins and 10 Magellanic penguins, the recorded foraging positions, covered an area of 11.3±8.3 km^2 and 13.4±9.5 km^2 respectively. The maximum distance reached for Humboldt penguins was 7.4±1.6 km whereas for Magellanic penguins it was 9.8±5.3 km. The major differences were found in the total distance covered at sea, where Magellanic penguins traveled on average of 61±27.7 km and Humboldt penguins covered 39.8±10.5 km on average (Table 1). Raya Rey et al (unpubl. data) described species and sex segregation for diving activities, where maximum depths for females and males of Humboldt penguins varies between 67 and 75 m respectively, meanwhile Magellanic penguins dive depths were 100 m for females and 67 m for males; however both species were seem to be more efficient during diving activities at shallow waters and near to the colony.

Both species utilized similar foraging areas, in particular the maximum areas covered for Humboldt penguins was 93 km^2 and 106 km^2 for Magellanic penguins (Fig. 4). Finally, Magellanic penguins overlap 56% of the 95% of the area used by Humboldt penguins, whereas Humboldt overlap in less than 50% the area used by Magellanic penguins (see Raya Rey et al., unpubl. data).

Designing boundaries for the MPA

The utilization areas from the kernel density analysis of Humboldt and Magellanic penguins were taken as a baseline for design the size and boundaries proposed (see Fig. 5). We considered three different options of MPAs based on the contours regions. The total areas of the MPAs proposed vary from a range of 150.4 km^2, 220.3 km^2, and 263.9 km^2 (Fig. 5). Although tracked birds represent less than 2% of the population, we considered their foraging range representative for the population during the breeding season.

Discussion

The coast of Chile has been recognized as one of the most productive coastal regions in the world due to the presence of highly productive coastal currents, upwelling influences, and nutrients transported into the ocean by rivers (Camus 2001, Escribano et al., 2003). In that context, the Humboldt Current system has been considered as a hotspot for seabirds because it supports a large number of multiple species year round (Spear and Ainley 2008). Although this region has been proposed as a prime candidate for best-practice environmental management (Lascelles et al., 2012), the existence of poor regulations to protect seabirds in the region has contributed to population decreases of several species. To date seabirds along the coast of Chile face diverse forms of human disturbance, such destruction of their habitat, degradation of nesting areas, pollution, and interaction with fishing gear (Simeone and Schlatter 1998, Skewgar et al., 2009, Pütz el al., 2011). Due to the lack of management for protecting seabirds at their breeding sites and in the foraging areas, many species are now threatened or endangered.

Because penguins play a critical role in the food webs, identifying areas for protecting these birds during the annual life cycle is required to mitigate human impacts on marine ecosystems. Available information on foraging ranges can be used to identify these areas (Thaxter et al., 2012). Although these birds utilized diverse areas and usually feed on high mobile preys, their foraging range may vary depending on the abundance and distribution of the target prey. Because the foraging areas may differ between colonies, regions and years providing the best data available for each species in the proposed area results crucial, and additionally should make it possible to evaluate potential conservation benefits of the proposed area (Lascelles et al., 2012). The use of representative data on foraging ranges, as presented in this paper, provides an initial approach for assessing a potential MPA. However, using representative data of foraging activity on it own is likely to result in the inclusion of substantial areas that may not be used by birds for feeding (Thaxter et al., 2009).

The degree of protection of an MPA for seabirds should be made as a function of their dispersal activity and site fidelity (Kenchington 1990). Here we observed that both Humboldt and Magellanic penguins showed high site fidelity and relatively low dispersal during early chick rearing. Copper et al. (1980) suggest that foraging ranges of African penguins during egg incubation also tend to take place daily and ranges are therefore likely to be similar to those during chick rearing. Considering that after the breeding season both penguin species dispersed over a coastal area ranging from the breeding site to 1,000 km northward and returned to the colony during the next breeding season (Pütz et al., unpubl. data), protecting areas used during the breeding season may thus help considerably to mitigate the threats faced by seabirds (Hooker 2006, Hooker and Gerber 2004).

To our knowledge, the datasets presented in this paper represent the most exhaustive information for mixed-colonies of *Spheniscus* penguins in Chile. Combining information on foraging ranges with other data on the foraging ecology of both species, such as habitat preferences, diving performance and efficiency to obtain the prey, allows for a more refined approach to delineating foraging areas that require protection (Thaxter et al., 2012). For instance a study conducted of diving behavior during chick rearing for both penguin species in the area, demonstrated that the birds have different depth ranges, however both attained maximum efficiency at shallower depth (Raya Rey et al. unpubl. data).

Although the sizes and boundaries of the potential MPA proposed in this paper only represent a portion of the foraging range for the both species, the smaller option is likely to preferred for effective management because of the reduced possibility of conflict with human activities. The proposed area currently offers many opportunities for the local community. Penguins in the area are the key attraction for local ecotourism (Skewgar et al., 2009). Therefore creating an MPA would not only provide a better scenario for penguins, it also would benefit the activity by mitigating the impacts of gillnets over the birds and other marine resources.

In terms of legal requirements, various mechanisms are proposed to maintain the pristine ocean and coastal zones, and the abundance of marine resources. Chilean administration offers legal instruments that can be used to develop MPAs, from fully protected zones (no-take zones) to management areas (multi-uses zones). Protected areas include Marine Parks, Marine Coastal Protected Areas (MCPAs), Natural

Sanctuaries, Marine Reserves, and National Monuments, and all of them can protect marine biodiversity or single species in coastal zones and in the open ocean (Fernandez and Castilla 2005). Formally, the Ministry of Defense (Subsecretary of the Navy), the Ministry of Economy (Fisheries Administration), the Ministry of Agriculture, and the Ministry of Education (Board of National Monuments) are the primary agencies that use legal instruments to protect the marine ecosystems. For instance the Subsecretary of the Navy plays a critical role, because the sea and the seafloor administratively falls under the Navy's jurisdiction (Fernandez and Castilla 2005). The Ministry of Economy is the agency that has the power to designate MPAs. Furthermore, in order to consider the designation of an MPA, a management plan is required and must be consistent with the Fisheries and Aquaculture General Act (Ley General de Pesca y Acuicultura or LGPA), and include the Ministry of Defense's Subsecretary of the Navy Subsecretaría de Marina, SUBMARINA) and the National Environmental Agency (CONAMA), as well include the direct participation of regional institutions, citizens and the local community (Trejo 2005).

In case the establishment of the proposed MPA occurs, there will be an important need to assess its effectiveness and monitor the benefits provided to penguins and marine resources. Because the MPA is proposed explicitly for conservation of Humboldt and Magellanic penguins, monitoring their activities, such as foraging range and efforts, reproductive success, and distribution patterns, will provide essential data with which to evaluate MPA effectiveness (Ronconi et al., 2012). For example, the Namibian Islands' Marine Protected Area (NIMPA), boundaries were established based on limited tracking data from African penguins, Cape gannet and Bank cormorant, but additional tracking after the MPA establishment confirmed that the MPAs design was adequate to encompass the foraging areas of several target species (Ludynia et al., 2012).

Finally, continued scientific research and the implementation of monitoring programmes are necessary to achieve the objectives proposed in this paper. Additionally, encouraging participation of the local community, NGOs and governmental entities would accelerate the process of establishing the MPA.

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REFERENCES

Allison, G.W., Gaines, S.D., Lubchenco, J., Possingham, H.P. 2003. Ensuring persistence of marine reserves: catastrophes require adopting an insurance factor. *Ecological Applications* 13, S8-S24.

Allison, G.W., Lubchenco, J., Carr, M.H., 1998. Marine reserves are necessary but not sufficient for marine conservation. *Ecological Applications* 8, S79-S92.

Boersma PD 2008. Penguins as marine sentinels. *Bioscience* 58:597-607.

Camus PA. 2001. Biogeografía marina de Chile continental. *Revista Chilena de Historia Natural* 74:587-617.

Cooper, J., 1980. Breeding biology of the jackass penguin with special reference to its conservation. In: Proceeding Pan-African Ornithological Congress, vol. IV, pp. 227-231.

Escribano, R., Fernández, M., and Aranís, A., 2003. Physical-chemical processes and patterns of diversity of the Chilean eastern boundary pelagic and benthic marine ecosystems: an overview. *Gayana* 67, 190-205.

European Commission, 2007. Guideline for the Establishment of the Natura 2000 Network in the Marine Environment. Application of the Habitats and Birds Directives. European Commission, Brussels.

Fernandez M. and Castilla J.C., 2005. Marine conservation in Chile: Historical perspective, lessons, and challenges. *Conservation Biology* 19: 1752-1762.

Hooker, S.K., 2006. Marine reserves and higher predators. In: Boyd, I.L., Wanless, S., Camphuysen, C.J. (Eds.), Top Predators on Marine Ecosystems. Their Role in Monitoring and Management. Cambridge University Press, pp. 347–360.

Hooker, S.K., and Gerber, L.R., 2004. Marine reserves as a tool for ecosystem-based management: the potential importance of megafauna. *BioScience* 54, 27-39.

IUCN. 2012 IUCN list of threatened species, http://www.iucnredlist.org; 2012 (access 05.06.2012)

Kenchington, R.A., 1990. Managing Marine Environments. *Taylor and Francis,* New York, 248 pp.

Lascelles, B.G., Langham, G.M., Ronconi, R.A., Reid, J.B., 2012. From hotspots to site protection: identifying marine protected areas for seabirds around the globe. *Biol. Conserv.*

Ludynia, K., Kemper, J and Roux, J-P. The Namibian Islands' Marine Protected Area: Using seabird tracking data to define boundaries and assess their adequacy. *Biol.*

Conserv. (2012) doi:10.1016/j.biocon.2011.11.014

Luna-Jorquera G 1996. Conservation assessment and management plan (CAMP): the Humboldt penguin *Spheniscus humboldti*. In: Croxall J, Cooper J, Ellis S (eds) Penguin conservation assessment and management plan workshop, Cape Town, South Africa. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, Minn., USA.

Micheli, F., Shelton, A.O., Bushinsky, S.M., Chiu, A.L., Haupt, A.J., Heiman, K.W., Kappel, C.V., Lynch, M.C., Martone, R.G., Dunbar, R.B., Watanabe, J., 2008. Persistence of depleted abalones in marine reserves of central California. *Biological Conservation* 141, 1078-1090.

Pérez-Muñóz C, G Lobos, MJ Oetiker 2007. Estudio capacidad de carga recreativa para actividades de turismo de observación de pingüinos, Monumento Nacional Islotes de Puñihuil, Isla de Chiloé, Chile. Centro de Conservación Cetácea en el marco del Proyecto Alfaguara.

Pichegru, L., Grémillet, D., Crawford, R.J.M. and Ryan, P.G. 2010. Marine no-take zone rapidly benefit endangered penguin. *Biol. Lett.* 6: 498-501

Pütz, K., Hiriart-Bertrand, L., Simeone, A., Riquelme, V., Reyes Arriagada, R. And Lüthi, B. 2011 Entanglement and Drowning of a Magellanic Penguin (*Spheniscus magellanicus*) in a Gill Net Recorded by a Time-depth Recorder in South-central Chile. *Waterbirds* 34(1):121-125

Raya Rey, A., K., Pütz, L., Hiriart-Bertrand, R., Reyes Arriagada, V.,Riquelme, B., Lüthi and A., Simeone Foraging behaviour during chick rearing of sympatric breeding Humboldt and Magellanic penguins at Islotes Puñihuil, southern Chile. In review *Emu-Austral Ornithology*

Reyes Arriagada, R., Hiriart-Bertrand, L., Riquelme, V., Simeone, A., Pütz, K. and Lüthi, B. Conservation of the mixed-species colony of Humboldt and Magellanic penguins in southern Chile: Is enough with an established Protected Area? In review *Bird Conservation International*

Rogers, A.D., Laffoley, D.d.A., 2011. International Earth System Expert Workshop on Ocean Stress and Impacts. Summary Report. IPSO Oxford, p.18.

Ronconi, R.A., Lascelles, B.G., Langham, G.M., Reid, J.B., Oro, D., 2012. The role of seabirds in Marine Protected Area identification, delineation, and monitoring: Introduction and synthesis. *Biol. Conserv.*

Schlatter R, Paredes E, Ulloa J, Harris J, Romero A, Vazquez J, Lizama A, Hernández C, Simeone A. 2009. Mortandad de pingüino de Magallanes (*Spheniscus magellanicus*) en Queule, Región de la Araucanía, Chile. *Boletín Chileno de Ornitología* 15: 78-86

Skewgar, E., A., Simeone and P. Dee Boersma 2009. Marine Reserve in Chile would benefit penguins and ecotourism. *Ocean & Coastal Mang.* 52: 487-491

Simeone, A. 2004. Evaluación de la población reproductiva del pingüino de Magallanes y del pingüino de Humboldt en los islotes Puñihuil, Chiloé. Informe final. Estudio financiado por la Fundación Otway (Chile) y Zoo Landau in der Pfalz (Alemania). Viña del Mar, 49 pp.

Simeone A, Bernal M, Meza J 1999. Incidental mortality of Humboldt penguins *Spheniscus humboldti* in gill nets, central Chile. *Mar Ornithol* 27:145–149.

Simeone, A. and Schlatter R.P. 1998. Threats to a mixed-species colony of *Spheniscus* penguins in southern Chile. Colonial *Waterbirds* 21: 418-421.

Spalding, M., Wood, L., Fitzgerald, C., Gjerde, K., 2010. Chapter 3: the 10% target: where do we stand? In Toropova, C., Meliane, I., Laffoley, D., Mattews, E., Spalding, M. (Eds.), Global Ocean Protection: Present Status and Future Possibilities. Brest, France: Agence des aires marines protégées. IUCN WCPA, Gland, Switzerland, Washington, DC and New York, USA, UNEP-WC-MC, Cambridge, UK, TNC, Arlington, USA, UNU, Tokyo, Japan, WCS, New York, USA, 96pp.

Spear, L.B., and Ainley, D.G., 2008. The seabird community of the Peru Current, 1980-1995, with comparisons to others eastern boundary currents. *Marine Ornithology* 36: 125-144.

Stoke, D.L., and Boersma, P.D., 1999. Where breeding Magellanic penguins forage: satellite telemetry results and their implications for penguin conservation. *Marine Ornithology*, 27: 59-65.

Tasker, M.L., Camphuysen, C.J., Cooper, J., Garthe, S., Montevecchi, W.A., Blaber, S.J.M., 2000. The impacts of fishing on marine birds. ICES *J. Mar. Sci.* 57, 531-547.

Thaxter, C.B., Lascelles, B., Sugar, K., Cook, A.S., Roos, S., Bolton, M., Langston, R.H.W., Burton, N.H.K., 2012. Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. *Biol. Conserv.* doi:10.1016/j.biocon.2011.12.009.

Tognelli, M.F., Silva-Garcia, C., Labra, F.A., Marquet, P.A., 2005. Priority areas for the conservation of coastal marine vertebrates in Chile. *Biol. Conserv.* 126, 420-428.

Toropova, C., Meliane, I., Laffoley, D., Mattews, E., Spalding, M. (Eds.), Global Ocean Protection: Present Status and Future Possibilities. Brest, France: Agence des aires marines protégées. IUCN WCPA, Gland, Switzerland, Washington, DC and New York, USA, UNEP-WC-MC, Cambridge, UK, TNC, Arlington, USA, UNU, Tokyo, Japan, WCS, New York, USA, 96pp.

Trejo P. 2005 Aprobado Reglamento de Parques Marinos y Reservas Marinas http://www.subpesca.cl ; [access 2.11.2012]

Wilson, R.P., Pütz, K., Peters, G., Culik, B.M., Scolaro, J.A., Charrassin, J.-B., Ropert-Coudert, Y.,1997. Long-term attachment of transmitting and recording devices to penguins and other seabirds. *Wildlife Society Bulletin* 25, 101– 106.

Worn, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, L.J., Watson, R., 2006. Impacts of biodiversity loss on ocean ecosystem services. *Science* 314, 787-790.

ANNEXED

Figure 1. Map of proposed MPA for mixed-colony of Humboldt and Magellanic penguins in southern Chile.

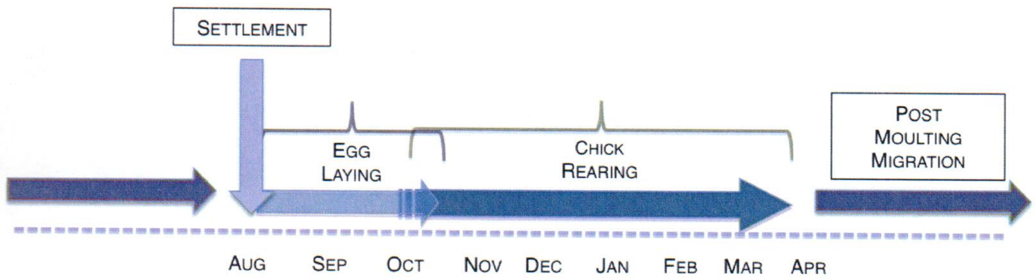

Figure 2. Timing of the breeding season for Humboldt and Magellanic penguins in Puñihuil islets.

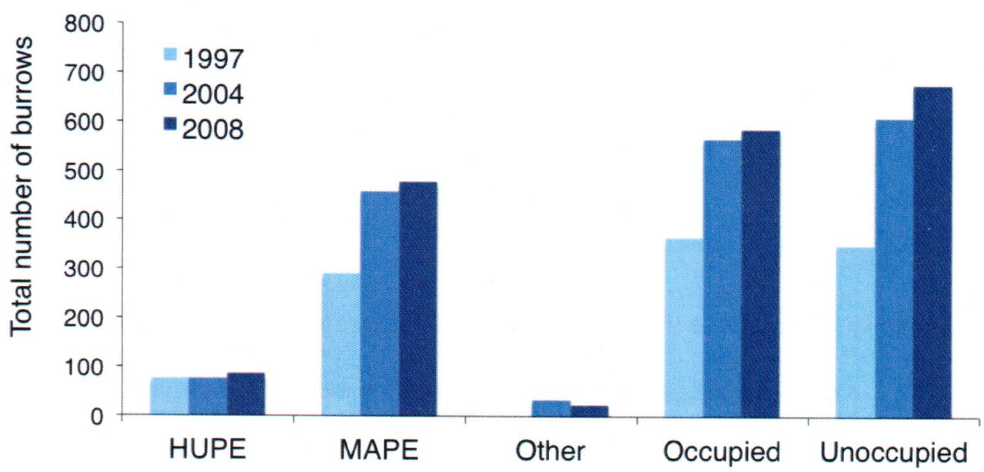

Figure 3. Total number of burrows counted in 1997, 2004 and 2008 for penguin pairs of the mixed-colony of penguins in Puñihuil Islets, Chiloé, Chile. Humboldt penguin (HUPE), Magellanic penguin (MAPE), burrows with chicks alone and hybrids penguins (Other), Occupied and Unoccupied. (Reyes Arriagada et al unpubl. data; modified by L. Hiriart-Bertrand).

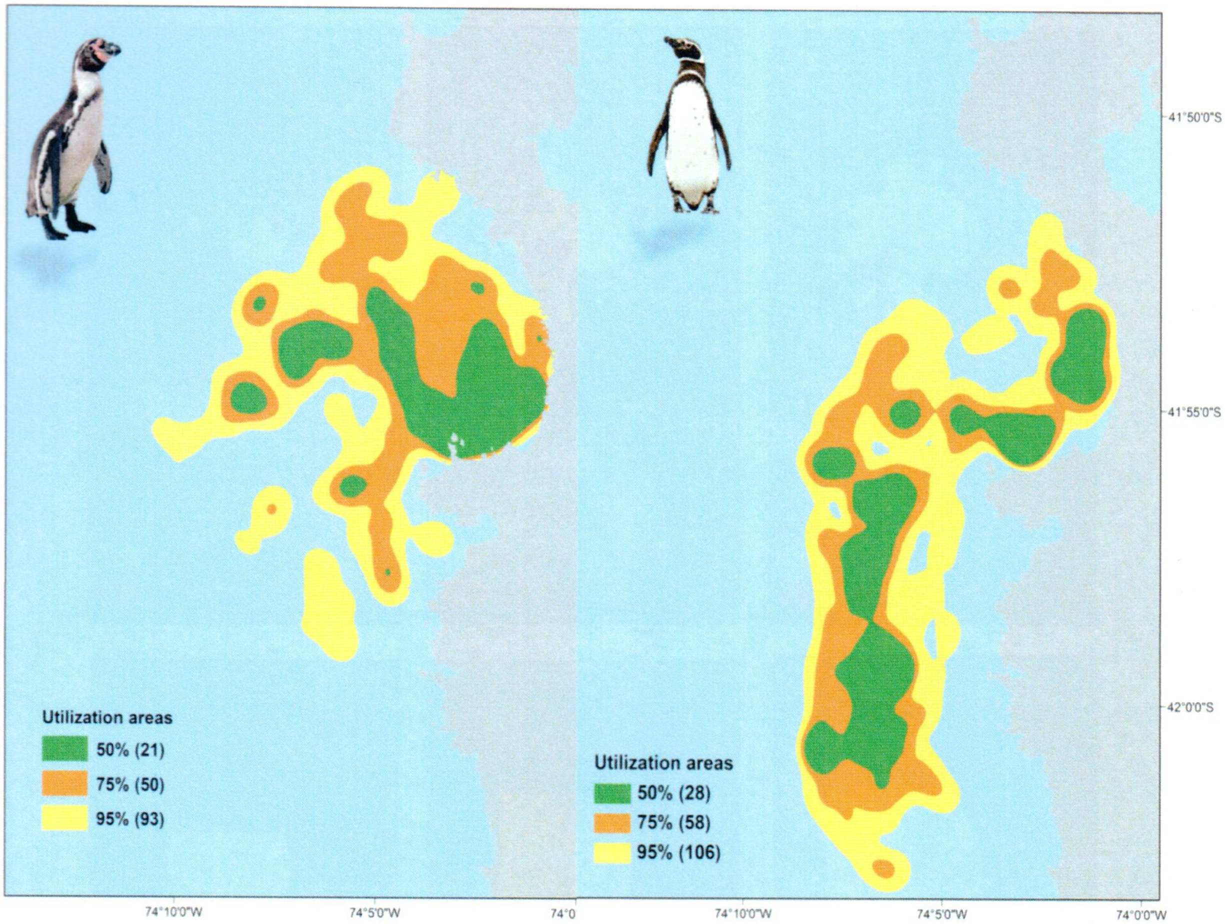

Figure 4. At sea distribution maps (50, 75 and 95% kernel contours) for Humboldt and Magellanic penguins. Numbers between brackets are utilized areas in km^2.

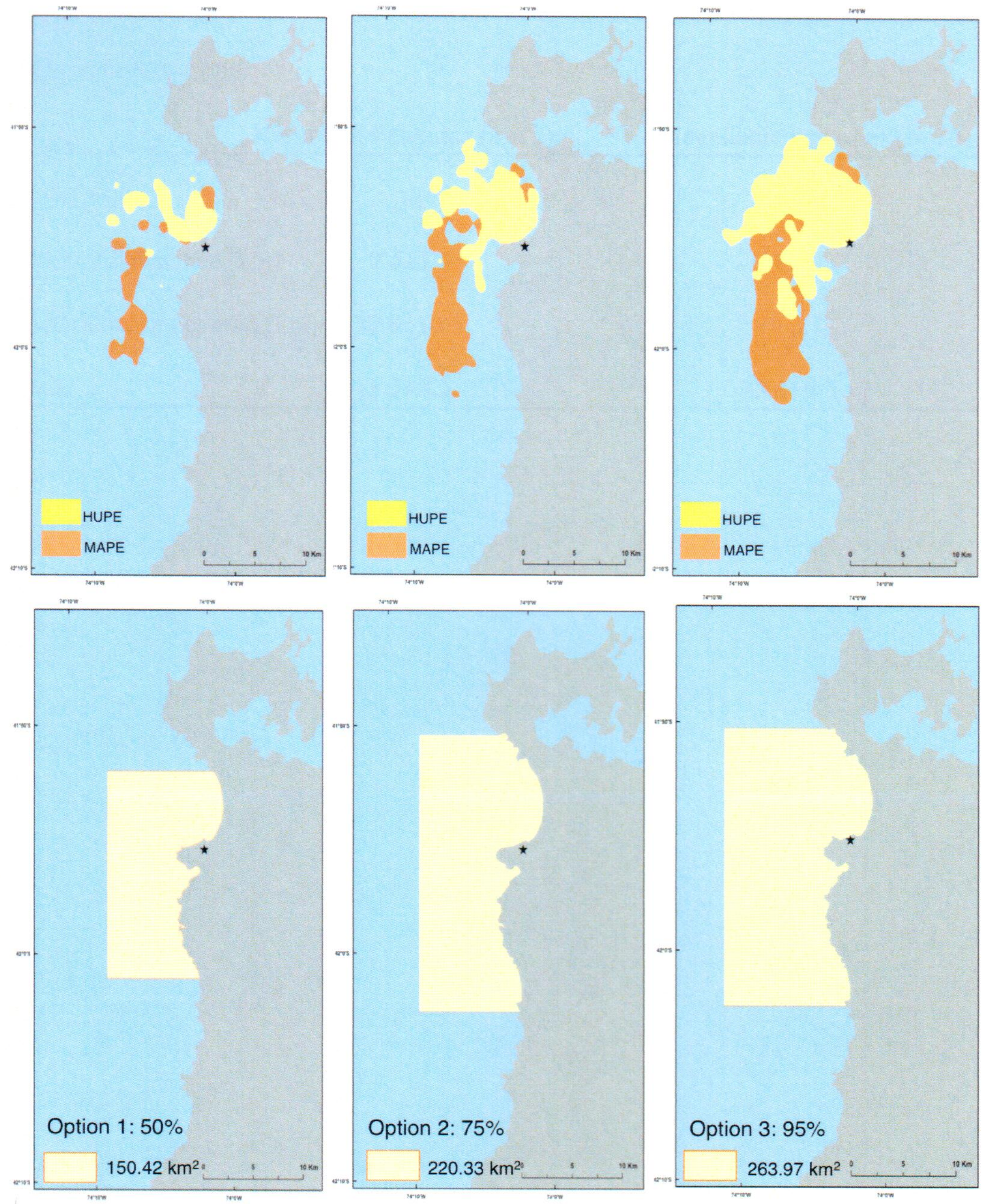

Figure 5. Kernel density analysis for Humboldt and Magellanic penguins, where 50% represent the most occupancy areas, whereas 75, 95% are the least occupied and the outline boundaries proposed for each scenario of the density analysis.

Table 1. Tracks characteristics of adults Humboldt and Magellanic penguins at Puñihuil islets, southern Chile.

	Humboldt Penguins (n=12)	Magellanic Penguins (n=10)
No. of trips	18	18
Maximum distance (km)	7.4±1.6	9.8±5.3
Total distance covered (km)	39.8±10.5	61±27.7
Area	11.3±8.3	13.4±9.5