

FORAGING RANGES OF HUMBOLDT PENGUINS *SPHENISCUS HUMBOLDTI* FROM TILGO ISLAND: THE CRITICAL NEED FOR PROTECTING A UNIQUE MARINE HABITAT

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ABSTRACT

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The largest population of Humboldt Penguins resides in a fertile archipelago of the north-central coast of Chile, formed by eight islands in proximity to upwelling centers of the Humboldt Current System. However, five of these islands lack legal protection. Here, we report the results of breeding Humboldt Penguins tracked while foraging from Tilgo Island. The average and maximum foraging radii around the colony were 22 km and 43 km, respectively. Our data indicate that trip ranges overlap areas proposed for industrial projects. Because Humboldt Penguins are sentinels of local ecosystem health, this underscores the value of expanding conservation zones in this unique marine location.

Key words: habitat degradation, breeding colony, penguin conservation, anthropogenic impact, parental care, coastal development

INTRODUCTION

Among the major drivers affecting global penguin populations are climate change, fisheries, introduced invasive species, habitat degradation, and ocean pollution (Trathan *et al.* 2015, Ropert-Coudert *et al.* 2019). All penguins species are central place foragers, which makes them highly sensitive to anthropogenic factors that influence foraging areas (Boersma 2008). Like most species of penguins, Humboldt Penguins *Spheniscus humboldti* have experienced substantial population decreases over the last decades (Vianna *et al.* 2014, Boersma *et al.* 2019). This species breeds in regions with increasing human presence, and thus, it is becoming ever more exposed to impacts related to anthropogenic activities (Simeone & Bernal 2000, Ellenberg *et al.* 2006).

The largest population of Humboldt Penguins is found on the north-central coast of Chile (29°00'–31°00'S; Vianna *et al.* 2014), in the Humboldt Archipelago. This archipelago is composed of eight small islands (< 6 km² and < 22 km from coast) and is associated with two upwelling centers of the Humboldt Current System (Thiel *et al.* 2007). Several endemic seabird species breed on these islands, and the zone is used as foraging habitat by a diverse group of marine vertebrates, including numerous cetacean species (Simeone *et al.* 2003, Weichler *et al.* 2004, Hertel *et al.* 2005, Luna-Jorquera *et al.* 2012, Toro *et al.* 2016). It has been estimated that the Humboldt Archipelago may harbor approximately 80% of the remaining total population of Humboldt Penguins (Mattern *et al.* 2004, Wallace & Araya 2015).

Among the eight islands of the Humboldt Archipelago, only three are protected as part of a national reserve and marine

protected area (see Fig. 1). The other five islands and surrounding waters remain unprotected. Thus, important breeding colonies of Humboldt Penguins, and other endemic species, remain vulnerable to accelerated coastal development. In fact, different development projects have been proposed for this coastal zone, including a thermoelectric power plant (Cárcamo *et al.* 2011) and two mining projects that involve the construction of industrial ports for mineral shipping.

Tilgo Island, the closest island to the coast of Chile in the Humboldt Archipelago, remains unprotected. Despite its small size, Tilgo Island has a breeding colony of *ca.* 2000 penguins (Vianna *et al.* 2014). Information is lacking about at-sea movements of penguins from Tilgo Island, and yet, it is located only 8 km and 13 km away from each of the proposed mining ports (Fig. 1). In this work, we report results of studies of at-sea foraging ranges of adult penguins from the Tilgo Island colony, with the aim of assessing the marine habitat space of parents during the breeding stage as it relates to the need to provide effective legal protection to the unique habitat of Humboldt Penguins.

METHODS

Study area

The Pacific coast of South America is ecologically influenced by the Humboldt Current System, an eastern boundary current with a northward flow and with centers of strong upwelling (Thiel *et al.* 2007). Within this region, the Humboldt Archipelago represents an important hot-spot of biodiversity, where the largest breeding population of Humboldt Penguins resides (Mattern *et al.* 2004,

Luna-Jorquera *et al.* 2012). Fieldwork was conducted on Tilgo island in the Humboldt Archipelago (29°00'–31°00'S) (Fig. 1) during the breeding season of 2018.

Study subject

The Humboldt Penguin is endemic to the Humboldt Current System. The species is listed as 'Vulnerable' by the International Union for the Conservation of Nature's Red List of Threatened Species (IUCN 2019), as 'Endangered' by the US Endangered Species Act, and is classified in Appendix I of the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES). The Humboldt Penguin is an endemic mesopredator and is considered to be a sentinel of the health of its local ecosystem (Boersma *et al.* 2007, Boersma 2008).

In Chile, Humboldt Penguins typically exhibit two well-defined breeding peaks, one during the austral fall (April–June) and the other during the spring (September–December; Simeone *et al.* 2002). Incubation requires 40–42 d, and chicks fledge at 10–12 weeks of age. Chicks are semi-altricial and require extended parental care before becoming fully independent (Ancel *et al.* 2013). The whole process, from incubation to fledgling, takes approximately 120 d (Paredes & Zavalaga 2001), and both parents take turns foraging at sea and feeding the chicks (Luna-Jorquera & Culik 1999, Taylor *et al.* 2002).

Tracking penguin trips

In the last week of November, we captured on the nest, by hand, 18 adult Humboldt Penguins that were rearing small chicks (< 1500 g). We tracked single foraging trips using automated GPS loggers, CatLog-S devices sealed in a heat-shrink epoxy casing (3.7 × 2.2 × 0.8 cm, 15 g, Catnip Technologies, Hong Kong). All devices were attached onto the penguin's backs with Tesa tape (see Luna-Jorquera & Culik 2000).

RESULTS

Among the 18 GPS loggers implemented, we were able to recover devices from 11 individuals (Fig. 1). The remaining devices came off accidentally and were not found upon recapture. The average foraging radius of Humboldt Penguins was found to be 22 km around Tilgo Island, with a maximum radius of 43 km (Fig. 1). The duration of individual trips varied between 14 and 36 h. We observed that the at-sea ranges of penguins around the breeding colony extended throughout the coastal zone and overlapped the area proposed for two industrial mining ports (Fig. 1).

DISCUSSION

The observed foraging ranges are in accord with previous studies conducted at other colonies of Humboldt Penguins. Although breeding adults can forage up to 90 km around a colony (Culik & Luna-Jorquera 1997, Culik 2001), they are usually found within 35 km the colony during the period of parental care (Luna-Jorquera & Culik 2000, Taylor *et al.* 2002, Boersma *et al.* 2007). Our results indicate that trips observed around Tilgo Island range widely, extending over a large coastal zone (Fig. 1).

Humboldt Penguins are highly philopatric and are central place foragers (Culik & Luna-Jorquera 1997, Dantas *et al.* 2019). For

species such as the Humboldt Penguin that breed on land but forage at sea, the breeding stage is particularly challenging. In order to provide adequate food for chicks and maximize reproductive success, parents must limit the duration and range of their foraging trips (Luna-Jorquera & Culik 2000, Taylor *et al.* 2002). Hence, the capacity of penguins to successfully raise young ultimately depends on the ability of breeding pairs to obtain food, and on the quality and health of the foraging habitat that is available. Thus, to ensure safe breeding conditions for penguins, both their colonies on land and their foraging habitat must be protected.

Coastal development and mining projects: a latent threat

The study site lies within the area where the largest part of the Humboldt Penguin population occurs. There are now proposals for two mining ports (Cruz Grande and Dominga) on the coast adjacent to the Humboldt Archipelago (Fig. 1). The proximity of these ports to Tilgo Island poses environmental risks associated with massive infrastructure construction and increased port activity,

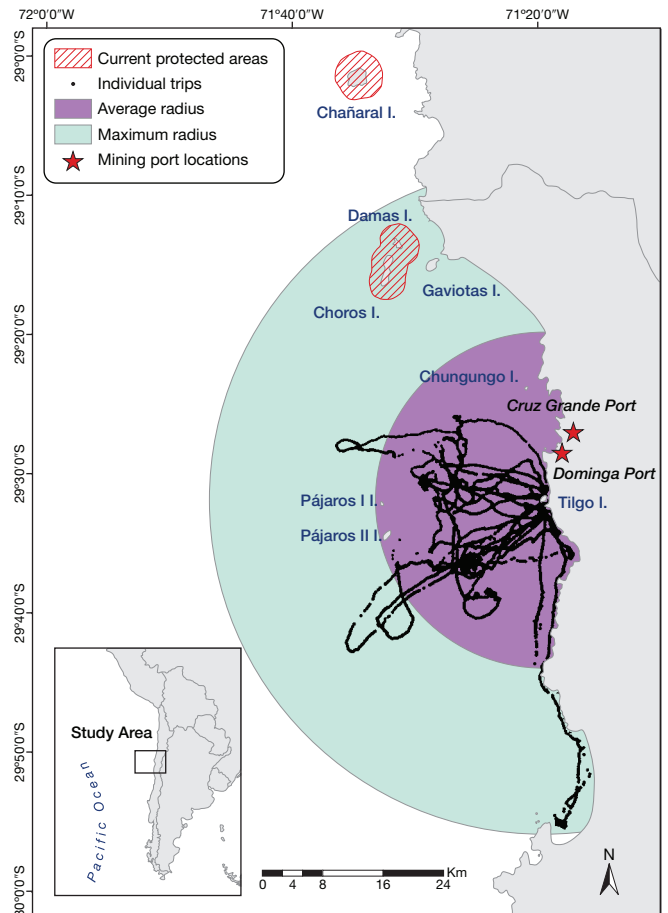


Fig. 1. Individual foraging trips of Humboldt Penguins with active nests and chicks at the Tilgo Island colony in spring 2018. Names in blue indicate the islands of the Humboldt Archipelago. Red stars show the locations planned for the construction of two mining ports. The red striped areas show current protected areas. The purple circle represents the at-sea average foraging radius based on 11 breeding penguins. The green circle is the radius of the maximum observed foraging distance. Dotted lines represent individual trips.

such as oil spills, mineral spills, sediment runoffs, introduction of invasive marine and terrestrial species, light and noise pollution, anthropogenic marine debris, and increased vessel traffic (see Trathan *et al.* 2015). These types of disturbances could lead to the degradation of the nesting and foraging habitat associated with the Tilgo Island breeding colony, negatively affecting reproductive success and the capacity for population growth (Boersma 2008, Ropert-Coudert *et al.* 2019). One of the justifications in support of these projects is the assumption that the mining ports are designed to operate outside the protected zones. While this is legally correct, our data show that Humboldt Penguins from Tilgo transit these waters while foraging to feed chicks.

The critical need to expand conservation areas

Although there are legally protected areas in the Humboldt Archipelago, these areas only extend one nautical mile out from the protected islands and do not encompass the majority of the islands of the archipelago (Fig. 1), i.e., those that contain important breeding colonies of Humboldt Penguins (Vianna *et al.* 2014), such as that of Tilgo Island. The scientific community and regional agencies have continuously argued for effectively protecting the Humboldt Archipelago by expanding the already-existing land and marine protection areas. Moreover, the effectiveness of protected areas for Humboldt Penguins has been questioned when colony-based foraging ranges are not properly taken into account (Werner *et al.* 2011). Our present work supports this critical issue. Trip ranges are expected to be even larger during the penguins' incubation period (Werner *et al.* 2011). Moreover, their use of foraging space is typically shared by a diverse seabird species assemblage, often forming multi-species feeding flocks (Weichler *et al.* 2004, Anguita & Simeone 2015). Accordingly, our results indicate that the planned locations for future port constructions on the northern coast of Chile, near Tilgo Island, requires reevaluation (e.g., Boersma *et al.* 2002, Soanes *et al.* 2016). We propose that continued research on penguin behavior is required in order to facilitate the delineation and monitoring of appropriate conservation areas for Tilgo Island and the rest of the Humboldt Archipelago.

The global population of the Humboldt Penguin is patchily distributed from central Peru to southern Chile and has undergone extreme fluctuations in numbers over the last decades (Luna-Jorquera *et al.* 2000, Paredes *et al.* 2003, Vianna *et al.* 2014). The accelerated rate of human development activities on the coast of Chile has significant potential to aggravate this species' delicate conservation status, including its continued decrease in population size (Croxall *et al.* 2012, Boersma *et al.* 2019). Detrimental anthropogenic impacts within irreplaceable breeding colonies, as identified in the current paper, represents an ever-increasing threat in Chile; hence, mitigation requires appropriate decisions now.

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