STRANDED HUMBOLDT PENGUINS *SPHENISCUS HUMBOLDTI* WITH BILATERAL BLINDNESS ALONG CHILEAN COASTS

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ABSTRACT

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Bilateral blindness is an important cause of mortality in penguin chicks. However, this pathological condition remains little explored for the endangered Humboldt Penguin *Spheniscus humboldti*. Here, we present the first spatiotemporal dataset detailing young Humboldt Penguins having bilateral blindness. Information was gathered from birds found stranded along the coast of continental Chile over a ten-year (2011–2021) period. We present a number of cases analyzed by geographical distribution, sex, body mass, and season. Preliminary analysis shows that 73.3% of cases were concentrated along Chile's central coast. Only 17.1% of individuals were sexed, and the distribution was slightly skewed in favor of males. Two temporal peaks were identified (2015 and 2019) in which slight decreases in body mass were observed. The highest incidence occurred in summer. This dataset will contribute to the understanding of the spatiotemporal mechanisms associated with bilateral blindness in Humboldt Penguins, a condition that can be related to pollution, climatic, and conservation issues.

Key words: biogeography, Humboldt Current, pathology, spatial distribution, aquatic birds

INTRODUCTION

Ocular lesions in one or both eyes are a common cause of partial or total vision loss in birds, as they result in the opacification of the clear ocular media (Álvarez-Varas *et al.* 2018). This results in the inability of the retina to process the image, either by preventing the transmission or relay of the message through the visual pathways (eye and optical nerves) or by hindering the final processing of the image in the visual cortex (Seruca *et al.* 2010). In marine organisms, blindness can also be caused by pollution; however, we have not found reports examining the association between blindness of marine bird species and environmental conditions.

Penguins' eyes play a significant role compared to other birds. Clear and binocular vision is essential for penguins both on land and underwater. Their eyes are also capable of color vision, and they can detect light in the ultraviolet and visible light portions of the spectrum (Dresp *et al.* 2005). In the southern seas of the Southern Hemisphere, penguins have been severely affected by marine habitat degradation (Dias *et al.* 2019, Richards *et al.* 2021). Indeed, 12 of the 18 penguin species have exhibited population decline and are considered Threatened (Ropert-Coudert *et al.* 2019).

In Chile, ten penguin species have been identified, half of which have declined in population during the last few decades due to human-caused decreases in reproductive success or increases in mortality. Penguins found stranded along the Chilean coastline exhibit different pathologies, with a small proportion of them being taken to rescue centers and surviving while others that appear dead are collected by Chile's National Fishery and Aquaculture Service (Servicio Nacional de Pesca y Acuicultura, SERNAPESCA). The surviving individuals are generally affected by intestinal parasites, aspergillosis, and malnutrition, among other pathologies (Fonteneau *et al.* 2011, Uhart *et al.* 2019). However, bilateral blindness is a scarcely studied pathology, and there is a lack of knowledge about its causes and etiology. Stranded Humboldt Penguins *Spheniscus humboldti* chicks on the coast of Chile are frequently observed with this condition, which is reported as "bilateral blindness" in the medical database of marine wildlife rehabilitation centers; there is no report of stranded chicks that are unilaterally blind. The Humboldt Penguin is considered a Vulnerable species according to the International Union for Conservation of Nature.

Observations of stranded individual Humboldt Penguins were concentrated along the coast of central Chile (29°S–35°S), including 402 cases between 2009 and 2016 (Toro-Barros *et al.* 2017). This species is distributed from Isla Foca, Peru (05°12′S, 081°12′W), to Islas Puñihuil, Chile (41°55′S, 074°02′W), with 45 colonies found from Arica to Chiloé in Chile (Simeone *et al.* 2018), mostly on coastal rocky islands (Paredes *et al.* 2002, Simeone *et al.* 2002). This species is very sensitive to human disturbance (Paredes *et al.* 2002), to heavy-metal contamination in north-central Chile (26°S–32°S; Celis *et al.* 2014), and to climatic variation (Simeone *et al.* 2002). Therefore, Humboldt Penguins face a series of environmental pressures that have caused a decline in reproductive success, as well as increased incidence of disease, mortality, and morbidity associated with stress and injuries. A particularly severe condition with which the species must cope is bilateral blindness, which also affects other bird groups

such as canaries, fowls, and turkeys (Ashton *et al*. 1973, Vickers *et al*. 1992, Cecchinato *et al*. 2014). Since environmental toxicity can lead to certain diseases as shown by Carneiro *et al*. (2014) for the Common Buzzard (*Buteo buteo*), bilateral blindness in Humboldt Penguins might be also one of them, and therefore understanding the spatiotemporal distribution of this pathology is required for effective management. Here, we assess the spatiotemporal pattern of bilateral blindness found in live stranded Humboldt Penguins along the coastline of continental Chile over the past decade.

METHODS

We assessed a proprietary database of Humboldt Penguins from the Fundación MundoMar, a nonprofit organization that has operated a marine animal rehabilitation program since 2010. Information was also provided by SERNAPESCA (http://www.sernapesca.cl), the local government agency in charge of rescuing marine wildlife and collecting related data. When a stranding event occurs involving blind Humboldt Penguins, the individual is delivered to the Fundación MundoMar. There, weight and sex are determined in most cases, and clinical and echography examinations are done to diagnose bilateral blindness and any other problems. Age is also determined, and all the stranded individuals recorded during our study were found to be chicks. Additionally, SERNAPESCA records the date and location where the individual was found. We compiled 65 events between January 2011 and January 2021 (Table S1 in the Appendix, available online; see https://doi.org/10.6084/m9.figshare.19427009.v1 for updates). We included only live individuals received by Fundación MundoMar or SERNAPESCA in our database, while dead stranded individuals were not analyzed in this study.

The data were georeferenced using a Geographic Information System, from which a map was generated with the specific location of stranded individuals by date, along with annual tallies of individuals by sex and body mass. We also performed a Kruskal-Wallis test with a post-hoc Tukey test to check for significant differences between seasons; these tests were developed in the R environment (Fig. S1).

RESULTS

Records of blind stranded Humboldt Penguins were mainly concentrated in north-central Chile, from the administrative region of Coquimbo to that of Valparaiso; only one record was found in each of the southernmost and northernmost regions (Fig. 1). Coquimbo and Valparaiso regions had 14 (21.5%) and 44 (67.7%) of the total records, respectively (Fig. 1). Within these regions, the Puchuncavi-Quintero shoreline zone had the highest number of stranded individuals (n = 23, representing 35.9% of all cases). Two peaks of stranding events occurred in the 2013–2015 and 2019–2020 periods; lower incidence occurred during two periods (2011–2012 and 2016–2018; Fig. 1 and 2).

The body masses of blind, stranded Humboldt Penguins exhibited a slight downward trend from 2011 to 2021. In fact, in the years 2011–2012, two individuals had a mean mass of 3.20 kg, while in 2013, eight individuals averaged 1.87 kg. During 2014–2015, the mean mass was 2.32 kg, while in 2016 and 2017, it was 1.66 kg and 2.32 kg, respectively. Finally, between 2018–2019 mean mass was 2.28 kg, while in 2020 and 2021, it reached 2.50 kg and 2.21 kg, respectively (Fig. S2A). Regarding the seasonal pattern of stranding events, the highest proportion of individuals was found during

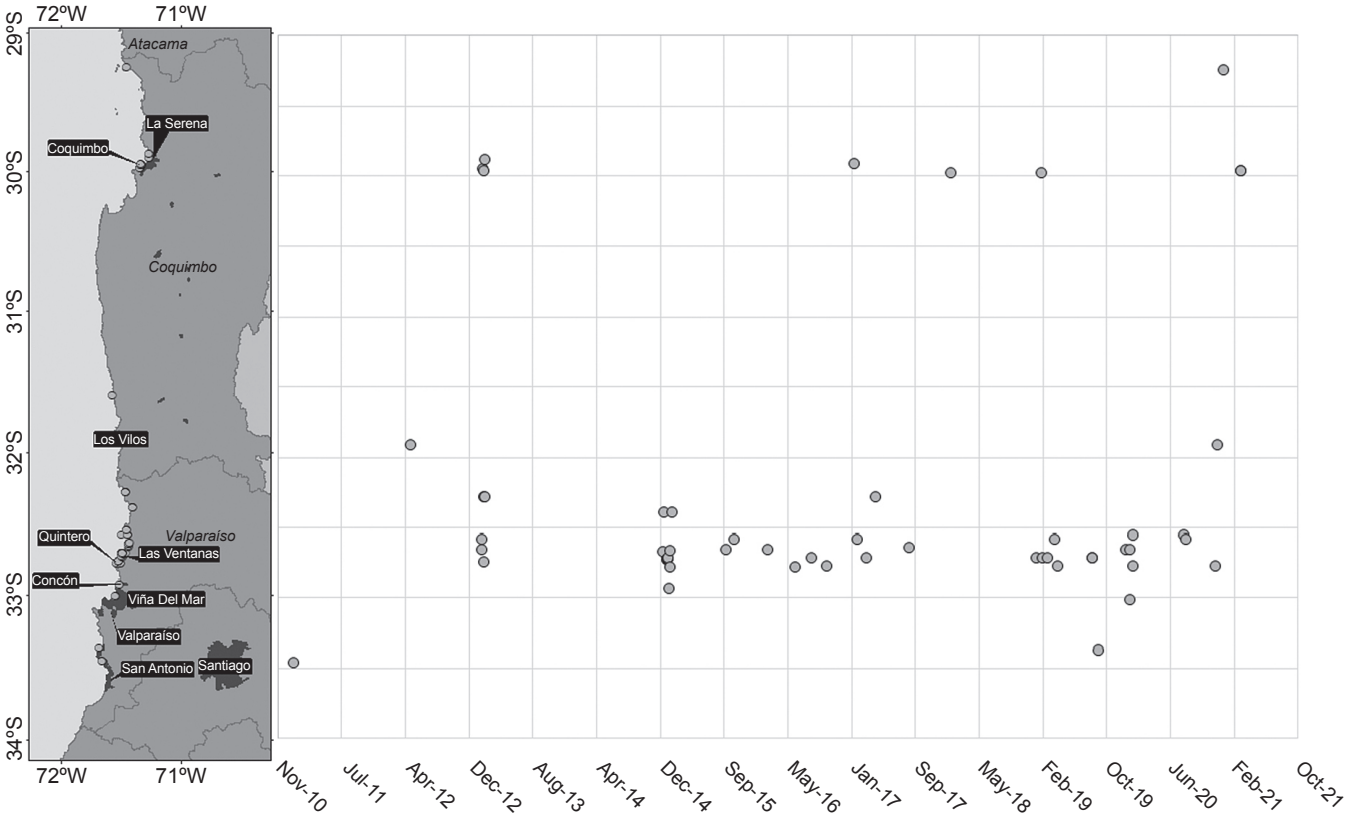

Fig. 1. Spatiotemporal distribution of stranded Humboldt Penguins *Spheniscus humboldti* by latitude and date. The map on the left corresponds to the specific location of each event, while the x-axis shows the date of the events.

summer ($n = 41$), followed by winter ($n = 9$, Fig. S2B). Only 17.1% of the total individuals were sexed, corresponding to 10.9% males and 9.4% females (Fig. S2B). The number of stranded individuals was significantly higher during summer compared to other seasons ($\chi^2 = 12.444$, $df = 3$, $p = 0.006$; Fig. S2C). A concentration of stranding events occurred during the summer of 2013 in the Valparaiso region (Fig. 2). From summer 2014 to summer 2019, an extended concentration of stranded individuals was recorded, including 20 individuals rescued mainly along the Puchuncavi shoreline (32°43′34″S, 071°24′54″W; Fig. 2).

DISCUSSION

Understanding the dataset from penguin ecology

Clinical examination of the stranded blind penguins at Fundación MundoMar reported healthy but animals emaciated because of extreme hunger. Echographic descriptions of 10 bilaterally blind Humboldt Penguins revealed 17 eyes with retinal detachment, 13 eyes with cataracts, 9 eyes with damaged vitreous membranes, and 1 eye with a damaged choroid membrane (Ortiz Sandoval 2019).

We found that a large proportion of stranding events occurred during summer, which coincides with the Humboldt Penguin reproductive season. Since records corresponded to fledglings, there could be an association with density-dependence, as observed in the Magellanic Penguin *Spheniscus magellanicus* (Pozzi *et al.* 2015).

Most penguins recorded here were not sexed, a limitation of our study. Previous studies in similar penguin species have shown that sex has an important relationship with their response to human disturbances and foraging strategies (Clarke *et al.* 1998; Ellenberg *et al.* 2009; Pichegru *et al.* 2013).

A slight decrease in body mass was found in Humboldt Penguins over time, possibly associated with resource depletion resulting from a reduction in the size of their main prey, the Peruvian Anchoveta *Engraulis ringens* (Canales *et al.* 2018). Based on our own measurements of healthy penguins, which have an average mass of 4.00 kg three months after hatching, stranded individuals weighed 1.66–3.20 kg, which represents a decrease of 58.5%–20.0%, respectively. Evidence shows that upon fledging, blind chicks of normal mass and age do not eat anymore because they are not able to see and catch their prey; some die at sea and others strand on coastal beaches (Simeone *et al.* 2018). The variation in the mass of stranded penguins may be determined by the time since they left the nest and appear stranded on the coastline. An adult Humboldt Penguin's weight ranges from 2.9 to 6.0 kg (Dunning 2007). It is important to remark that the age of fledging (independence from the parents) in Humboldt Penguins is 70–90 days (chicks), when

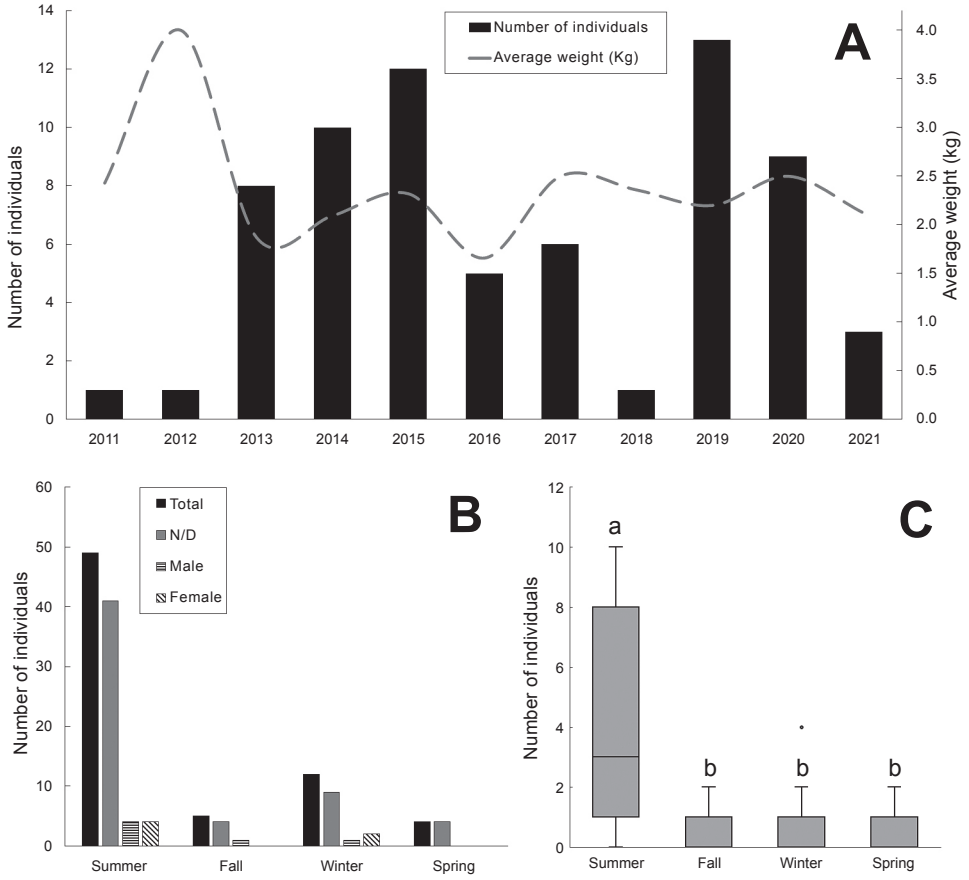

Fig. 2. Time series of stranded Humboldt Penguins *Spheniscus humboldti*. A) Total number of individuals and their average body mass per year, B) total number of individuals by sex (N/D = not determined), and C) boxplot of the total number of individuals recorded per year (letters represent pairwise differences from post-hoc comparisons); the point above the Winter plot is an outlier.

the young weigh 3.0–3.6 kg, according to AZA Penguin Taxon Advisory Group (2014). In this sense, our results suggest a serious malnutrition status of the stranded individuals on Chilean coasts.

We found a high concentration of cases on the coast of north-central Chile (Coquimbo and Valparaiso regions), which could be associated with three main factors: A) sampling biases arising from the high human population in this zone, which positively influences the rescue effort (Toro-Barros *et al.* 2017); B) higher levels of human disturbance in this area due to port and fishing activity, as well as high concentration of pollutants from thermoelectrical plants and industries (Meza *et al.* 2018); and C) correlation with the concentration of penguin colonies in Chile—95% of breeding colonies are located in Coquimbo region, which is one of the zones most affected by stranding events (Simeone *et al.* 2018).

Linking data and future research

We presented here the first systematic spatiotemporal report of bilateral blindness in Humboldt Penguins, providing a novel dataset for the study of this pathology and the development of future studies on this and other penguin species. We recommend using our database in combination with measurements of heavy metals, water temperature, salinity, chlorophyll, and fishing efforts, among other factors. The specific cause of bilateral blindness remains unclear, but it is likely attributable to pollution and habitat resource depletion. Our dataset will contribute to a better understanding of this important pathology, providing valuable information for penguin conservation.

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