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Looking for new emperor penguin colonies? Filling the gaps

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ABSTRACT

Detecting and predicting how populations respond to environmental variability are crucial challenges for their conservation. Knowledge about the abundance and distribution of the emperor penguin is far from complete despite recent information from satellites. When exploring the locations where emperor penguins breed, it is apparent that their distribution is circumpolar, but with a few gaps between known colonies. The purpose of this paper is therefore to identify those remaining areas where emperor penguins might possibly breed. Using the locations of emperor penguin breeding colonies, we calculated the separation distance between each pair of geographically adjacent colonies. Based on mean separation distances between colonies following a circumpolar distribution, and known foraging ranges, we suggest that there may yet be six undiscovered breeding locations with half of these in Eastern and the remainder in Western Antarctica. Productivity in these regions suggests that food resources are likely to sustain emperor penguin populations.

Our analysis highlights a fundamental requirement, that in order to predict how species might respond to regional climate change, we must better understand their biogeography and the factors that lead to their occupation of particular sites. Regarding emperor penguins, remote sensing should target the identified gaps apparently devoid of penguins in order to update the total number of colonies, to re-evaluate both the regional and global population of emperor penguins, and to gain a better understanding of their biogeography.

1. Introduction

The climate of our planet is undergoing regional and global changes, which are driving shifts in the distribution and phenology of many plants and animals (Hansen et al., 2013). There are a number of ecosystems and communities where the physical drivers of ecological change might become apparent before anywhere else. For example, the impact of climate changes is more visible in coralline ecosystems, where small variation in temperature can lead to the massive bleaching of coral reefs (Hoegh-Guldberg et al., 2007). These climate changes are also visible in polar ecosystems where, for instance,

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small variation in temperature and sea ice cover can alter seabird populations (Croxall et al., 2002; Jenouvrier et al., 2012; Lynch and LaRue, 2014; Lyver et al., 2014). These regions provide examples that may foreshadow future events elsewhere on the planet.

Here, we focus on the southern polar region, which includes one of the most rapidly warming areas of the planet. For example, over the last 50 winters, the sea-level mean annual air temperature of the Antarctic Peninsula has become up to 6 °C higher than on the eastern side of the Antarctic continent (Reynolds, 1981; Turner et al., 2005; Malvaney et al., 2012). Among birds adapted to live in this extreme and variable environment, penguin species are the best known. As with other penguin species inhabiting more northerly locations, Antarctic penguins are restricted to a limited breeding latitudinal range at the shoreline of the continent (Ancel et al., 2013a), thereby limiting their ability to track latitudinally climate changes (Forcada and Trathan, 2009). Detecting and predicting how penguin populations respond to environmental variability represents a crucial challenge for their population management and their conservation (Jenouvrier et al., 2014; Trathan et al., 2014). This is particularly true for populations that exist at high latitudes, many of which are already exhibiting changes in population dynamics associated with global warming (Boersma, 2008; Baylis et al., 2012; Boersma and Rebstock, 2014; Lescröel et al., 2014). Notably this is the case for the emperor penguin (*Aptenodytes forsteri*), the only bird species that breeds in the midst of the Austral winter on the Antarctic continent (Stonehouse, 1952; Prévost, 1961).

Emperor penguin breeding sites are found at the edge of the Antarctic continent between latitudes 64°S and 77°S (Woehler, 1993; Lea and Soper, 2005; Ancel et al., 2013a). Within this circumpolar high-latitude distribution, the emperor penguin almost always breeds on stable fast ice near the coast (Mellick and Bremers, 1995; Coria and Montalti, 2000; Todd et al., 2004; Trathan et al., 2011), but a number of colonies have been reported on ice shelf (Wienecke, 2012; Fretwell et al., 2014) or land (see references in Fretwell et al., 2012, 2014) rather than on sea ice. Breeding colonies are usually located in areas where icebergs and ice cliffs shelter them from the prevailing winds (Prévost, 1961; Kooyman, 1993), but not far from open sea or polynyas, biologically productive areas of open water or reduced sea ice cover within the pack ice, where they feed (Ancel et al., 1992; Kooyman, 1993).

Available data on the abundance, distribution and phenology of the emperor penguin are far from complete. For instance, its phenology is only well known at the Pointe Géologie archipelago (67°S, 140°E) in Terre Adélie, where the colony has been surveyed for more than 60 years (Prévost, 1961). Generally, it is assumed that the phenology of all other colonies reflects that in Terre Adélie. The lack of information regarding other colonies is generally due to the logistic difficulties of reaching them. Indeed, due to the persistence of sea ice, few ships are able to reach most colonies before post-breeding adults disperse in early summer. During the breeding season in winter, access to colonies is even more difficult or impossible due to prevailing bad weather conditions and extensive pack ice.

Until recently, the location and size of emperor penguin colonies usually involved population counts and mapping on the ground (Prévost, 1961; Lea and Soper, 2005; Wienecke, 2010) or aerial photographs (Wienecke, 2012; Ancel et al., 2014; LaRue et al., 2015). Yet, these methods are laborious, time consuming and costly. As access to colonies is generally very difficult, it appears that a process of discovery is now best undertaken using remote sensing data from satellites (Barber-Meyer et al., 2007; Fretwell et al., 2012; LaRue et al., 2015). Indeed, several studies have recently demonstrated the utility of such remote-sensing imagery to identify and estimate the abundance of emperor penguin colonies (Barber-Meyer et al., 2007; Fretwell and Trathan, 2009; Fretwell et al., 2012, 2014). However, the total number of colonies remains uncertain. Currently, 54 colonies are thought to exist around the Antarctic continent (Fretwell et al., 2012, 2014; Wienecke, 2012; Ancel et al., 2014; LaRue et al., 2015). Of these, 48 are situated on fast-ice, four are permanently or occasionally located on ice-shelves (Barrier Bay, Shackleton Ice Shelf, Larsen Ice Shelf, Rupert Coast; (Fretwell et al., 2014)), one on rock (Taylor Glacier) and one on or near a frozen lake (Amundsen Bay). Four colonies have been recently identified by remote sensing and subsequently visited; two close to the Mertz Glacier and one close to Ragnhild during the austral summer of 2012–13 (Ancel et al., 2014), and one at Rothschild Island during 2015–2016 (Trathan et al., unpublished). The most recent satellite surveys include use of multiple images for each colony, with fine spectral and spatial resolution and high temporal resolution. Nevertheless, heavy cloud cover over the course of the breeding season may mean that colonies might be missed by satellite surveys. Detection during the winter is not feasible as optical satellite data is restricted by the lack of light. Further, especially towards the end of the breeding season, the break-out of sea ice may reduce the probability of detecting colonies. Complementary methods such as high-resolution imagery must therefore be found to locate these potentially missing colonies in winter.

When exploring the locations where emperor penguins breed, it is apparent that their distribution is circumpolar, but with a few gaps between known colonies (Fretwell et al., 2012). However, it is not yet known whether such gaps are actually devoid of emperor penguins, or if insufficient effort has been focussed on these regions to find if colonies actually exist. Interpreting the existence of a gap is complex as such a gap might truly result from low resource availability and/or inadequate sea ice structures and/or inadequate climatic conditions leading to a true absence of colonies, or alternatively the observed gap might result from a lack of observation effort. The purpose of this paper is therefore to identify regions, which might plausibly shelter emperor penguin breeding sites that we might be missing. Ultimately, remote sensing should target these gaps in order to update the total number of emperor penguin colonies, to re-evaluate both the regional and global population of emperor penguins, and to gain a better understanding of their biogeography.