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Conservation of migratory Magellanic penguins requires marine zoning

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ABSTRACT

Conservation of migratory species requires an understanding of their migration path and pattern. We used band returns and satellite tracking to characterize the seasonal migration of Magellanic penguins breeding in southern Argentina, with the purpose of identifying an effective conservation approach for this species. Band returns show these penguins migrate annually to the coastal waters of northern Argentina, Uruguay, and southern Brazil, an average one-way distance of approximately 2000 km, and a modal distance of 2300–2400 km. Satellite data indicate that the penguins follow a migration corridor within 250 km of shore. Mean migration distance varied among years. Juveniles migrated farther on average than older birds, although migration distance of different age classes overlapped substantially. Mortality rates during migration were higher among younger birds, and juvenile mortality rate during migration was inversely correlated with cohort survival, indicating that mortality during migration is an important determinant of population recruitment. A minimum of 13% of the migration-period mortality we recorded resulted from fisheries bycatch and oil pollution. Because of the penguin's mode of travel (swimming at or near the surface), the large spatial extent of its migration, and the intensity of human use of the area, effective conservation through conventional coastal marine reserves is unlikely. Marine zoning is an alternative that could provide the spatial scale and flexibility necessary to accommodate both penguin migration and human activities. As the waters traversed by Magellanic penguins are among the most threatened in Latin America, zoning for protection of this wide-ranging and charismatic species can also protect regional biodiversity.

1. Introduction

Migration poses a major challenge for conservation of many animal species (Robinson et al., 2009; Terborgh, 1989; Wilcove, 2008). Depending on favorable conditions in more than one seasonal habitat, as well as along the travel routes between those habitats, migratory species are vulnerable to human-caused environmental changes in multiple, often widely separated, locations (Martin et al., 2007; Primack, 2010; Reid and Miller, 1989). Furthermore, for species that migrate long distances, particularly top predators (Hooker et al., 2011), economic, political, and logistical factors make effective conservation difficult to achieve (Nevins et al., 2009).

These challenges notwithstanding, conservation efforts that do not address species' migration requirements are likely to fail (Martin et al., 2007; Webster et al., 2002). Successful conservation measures for migratory species must protect seasonal habitats as well as migration corridors; for many marine vertebrates, these measures must be large-scale and dynamic (Hyrenbach et al., 2000). Design of effective protections requires a comprehensive understanding of species' migratory routes – including the range of variation in those routes – to identify and effectively respond to points of conflict with human activities (Costa et al., 2012; Schofield et al., 2013).

The migrations of flying birds have long been the object of scientific study (Berthold, 2001); more recently recognized is the migratory nature of many flightless birds, among them, several species of penguins (Davis and Renner, 2003; García-Borboroglu and Boersma, 2013). Logistical constraints have prevented comprehensive monitoring of penguin migrations, however satellite and geolocation sensor tracking of small numbers of individuals has documented long distance seasonal movement in some species (e.g., Ballard et al., 2010; Boersma, 2012; Davis et al., 2001; Pütz et al., 2006; Trivelpiece et al., 2007).

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The Magellanic penguin (*Spheniscus magellanicus*) is a migratory upper trophic level predator that breeds along the coasts of southern Argentina and Chile and the Falkland/Malvinas Islands (Boersma et al., 1990, 2013). Although the species' overall population trend is uncertain (Boersma et al., 2013), it is declining at its largest breeding colony (Boersma, 2008) and is subject to increased mortality associated with human activities such as offshore petroleum extraction and transport (Boersma, 2012; Gandini et al., 1994; García-Borboroglu et al., 2006, 2008), commercial fishing (Boersma and Stokes, 1995; Cardoso et al., 2011), and perhaps climate change (Boersma, 2008; García-Borboroglu et al., 2010). As a result of these threats, the species is classified as "Near Threatened" on the IUCN Redlist (IUCN, 2012).

In the southwest Atlantic (southern Argentina and the Falkland/Malvinas Islands), where the majority of the population occurs (Schiavini et al., 2005), Magellanic penguins are present at their colonies only during the breeding and molting periods (September–April; Boersma et al., 1990), and spend the rest of the year at sea (Boersma et al., 2013). Satellite tracking of adults departing colonies following the breeding season indicates initial annual northward movement (Pütz et al., 2000, 2007; Stokes et al., 1998); however their whereabouts during most of the non-breeding season are not known with precision. Results of a small banding study (Daciuk, 1977), discoveries of oiled birds (García-Borboroglu et al., 2006), and anecdotal evidence (see below) indicate that the penguins migrate north as far as the southern coast of Brazil and, rarely, as far as northern Brazil (Boersma et al., 1990; García-Borboroglu et al., 2010; Ramos da Silva et al., 2012). Given that the primary threats to the penguins occur in the marine environment, a more precise and comprehensive picture of their migration and wintering areas is needed to design conservation measures to protect them.

To investigate the migratory movements of Magellanic penguins, we used a 30 year record of band recoveries from a large (approximately 60,000 birds banded), long-term study at Punta Tombo, Argentina, the largest breeding colony of this species (approximately 20% of the Argentine population; Boersma et al., 2013). Carcasses of penguins that die at sea normally float and wash up on beaches (Gandini et al., 1994; pers. obs.), and live penguins tend to come ashore when sick or injured (García-Borboroglu et al., 2006; pers. obs.). As Magellanic penguins do not appear to frequent waters far from shore during the non-breeding season (Boersma, 2012; Stokes et al., 1998), the locations of penguins on beaches should correspond to their recent locations at sea. Because penguin carcasses persist on beaches for only a short time (Gandini et al., 1994), and because of our public information effort (see below) and a continuously inhabited coastline, the record of discoveries of banded birds on beaches should reflect the large-scale spatial and temporal patterns of penguin movement along the South American coast. To provide finer scale information about this movement, we complemented band return data with satellite tracking of migrating penguins departing Punta Tombo following the breeding season (Stokes et al., 1998; this study). While satellite data cannot cover the entire migratory period, they provide an independent and more precise record of penguin movement, including distance from shore, which is not available in the coarser-scale band return data.

We expected that our data would reveal both the general pattern and the variation in Magellanic penguin migratory behavior. In addition to individual variation within age classes, migration distance may be greater for juveniles and young adults than for breeding adults because younger age classes are not constrained by the colony attendance requirements of breeding and chick rearing. As prey conditions strongly influence Magellanic penguin foraging patterns (Boersma et al., 2009), penguin migratory activity may also vary by year due to inter-annual variation in prey location and abundance.

The description of the penguin's migratory behavior that emerges from our data can be used to identify the parameters of effective conservation for this species in its marine environment. As a large and mobile predator, the Magellanic penguin is unlikely to be protected by small fixed-location coastal marine reserves, and larger-scale approaches, such as marine zoning, may be more appropriate (Boersma and Parrish, 1999; García-Borboroglu et al., 2008). Such approaches require detailed and comprehensive information on the spatial and temporal dimensions of the species' habitat use and movements (Costa et al., 2012; Hooker et al., 2011). Thorough understanding of the Magellanic penguin's migratory movements and winter range, along with its nesting and foraging patterns during the breeding season (Boersma et al., 1990, 2007; Boersma and Rebstock, 2009a), can provide the informational basis for an effective conservation plan for this species.

2. Methods

2.1. Band return study

As part of a breeding biology study of Magellanic penguins, we banded 58,232 penguins at the largest colony of the species, Punta Tombo, Argentina (44° 02′S, 65° 11′W), from 1983 to 2010 (see Boersma et al., 1990). We also banded approximately 2000 penguins at colonies farther south along the Argentine coast. At the time of banding we recorded each bird's location and age class (chick, juvenile, adult). We banded chicks at their natal colony just before they fledged, and juveniles (fledged the previous year) at colony beaches where they congregate before or during their molt to adult plumage; hence these birds were of known-age. Birds banded as adults were of unknown age, but nearly all were banded as breeders, meaning they were at least four years old, the earliest age at which Magellanic penguins typically breed (Boersma and Rebstock, 2009b; Rafferty et al., 2005).

Bands were stainless steel (Lambournes-Porzana, East Sussex, UK). Each was custom fitted to the base of the penguin's left flipper, with the side of the band bearing an identifying number visible to an observer (Boersma and Rebstock, 2010). On the inside of the band was a message in Spanish: "Send to the Natural Science Museum, Buenos Aires, Argentina." In 1983 and 1984, the office of Tourism of the Province of Chubut, Argentina, distributed posters to government offices, museums, and individuals in coastal areas, asking people to look for and report banded penguins on beaches.

Nearly all (99%; $n = 298$) reports of band recoveries we received included the band itself or a written record of the band number, which allowed us to reference our banding records to determine the penguin's colony of origin, age at banding, and the date on which it was banded. Most reports (86%; $n = 258$) also included the date the penguin was found. Those that did not include at least the month and year ($n = 42$) were assigned the date the report was mailed to the museum. All reports included a location, and most of these were specific (a town, point, beach, etc.). For reports ($n = 22$; 7%) that merely indicated a substantial stretch (*ca* 100–500 km) of coastline (e.g., Rocha, a province in Uruguay with a 170 km coastline), we assigned the midpoint of the identified coastline as the recovery location. Many reports included additional information on the condition of the bird, e.g., whether it was alive, had petroleum on its feathers, was in a fishing net, etc. Because we were interested in penguin locations during migration, we excluded reports of bands recovered at breeding colonies.

To determine survivorship of birds across years, we searched for banded birds throughout the colony at Punta Tombo every breeding season (September to March) and at other colonies when we were able to visit them. We also searched beaches at Punta Tombo at times of year when large numbers of juveniles and other