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Apex scavenger movements call for transboundary conservation policies

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A B S T R A C T

Current changes in the environment and increases in threats to wildlife have prompted the need for a better understanding of species' conservation requirements. Strategies for the conservation of large-sized animal species with large home ranges have included the creation of large protected areas, or for migrants, the creation of protected breeding, stop-over and wintering areas. We aim to describe the movement behaviour of Andean condors (*Vultur gryphus*), and to relate it to its significance in the conservation of this species and its environment. We examine whether current conservation strategies are sufficient to ensure the daily requirements of the species, and evaluate the degree to which breeding and foraging areas are covered by protected areas. We present as a new challenge the conservation of large-sized species that perform daily long-range movements across a number of political and ecological borders. Andean condors tagged with GPS-satellite transmitters make long daily flights from their breeding areas (mountains in Argentina and Chile) to their feeding areas (the steppe in Argentina) crossing over the Andean Cordillera. These flights demonstrate that current conservation strategies are insufficient to protect species with such daily movement patterns, and that new approaches are needed. Thus, it is necessary to gain a more in-depth knowledge of the movement ecology of these organisms through individual-level approaches integrating intrinsic (reproductive and foraging behaviour) and extrinsic (political and geomorphological boundaries) factors that shape movement patterns. Conservation efforts must include international cooperation aiming to combine the conservation of flagship species, the management of public and private lands, and the maintenance of valuable ecosystem services.

1. Introduction

Under the current extinction crisis, conservation policies that transcend political boundaries are indispensable in dealing with large-scale conservation issues (Abbitt et al., 2000; Donald et al., 2007; Barnosky et al., 2011). It is indisputable that the size of a protected area is key to ensuring the maintenance of populations, ecosystems and ecological processes (Dudley, 2008). However, the conservation of wide-ranging species that move between countries or even between continents poses challenges that exceed these common approaches (Wilcove and Wikelski, 2008; Block et al., 2011).

Conservation of wide-ranging vertebrates, such as large mammals, usually focus on the maintenance of strictly protected areas with a general criterion of 'bigger is better' (Wielgus, 2002; Du Toit et al., 2003; Thirgood et al., 2004; but see Press et al., 1996). Although effective in some cases, those strategies may not be appropriate for flying organisms (birds, bats, insects), able to move over huge distances. This is especially true for migratory animals alternatively occupying spatially distant breeding and wintering grounds. In such cases, conventions for coordinated conservation strategies in the two extremes of the distribution areas and, in some cases, also at stop-over points along migration routes, are mandatory (Milner-Gulland et al., 2011). Other species, on the other hand, do not migrate but travel large distances over short time periods and are continuously exposed to changing threats. Their patterns of movement have not been well considered in conservation efforts.

Here, we call attention to the necessity of implementing new models of transnational strategies for the conservation of large vertebrates that perform long-distance movements on a daily basis. This is the case of avian scavengers, the largest flying vertebrates on the planet, whose populations are increasingly endangered potentially triggering the loss of key ecosystem services

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(Ferguson-Lees and Christie, 2001; Markandya et al., 2008; Ogada et al., 2012). Our study model was the Andean condor (*Vultur gryphus*), a large body-size top scavenger with astounding flight capacities (De Martino et al., 2011; Ferguson-Lees and Christie, 2001; Shepard et al., 2011). Conservation programs for these birds have mainly focused on reintroduction strategies (BirdLife International, 2012; Lambertucci et al., 2013). However, specific conservation designs considering their pattern of movement and home ranges are lacking. Our aim was to describe the movement behaviour of Andean condors and relate it to its significance in the conservation of this species and its environment. We also evaluate the degree to which breeding and foraging areas are covered by protected areas. In particular, we examine whether current conservation strategies, mainly based on the protection of pristine ecosystems, are sufficient to ensure the daily requirements of a population distributed in two countries (Argentina and Chile) along either side of the Andean Cordillera.

2. Methods

2.1. Study species

The Andean condor inhabits the Andean Mountains throughout South America and adjoining hills in central Argentina (Ferguson-Lees and Christie, 2001). It is among the largest flying birds in the world, with a 3 m wingspan and a weight of up to 16 kg. Condors are at the limit of flight capacity due to their size and weight (Pennycuick and Scholey, 1984; Shepard and Lambertucci, 2013). This species, considered as 'Nearly Threatened' worldwide and endangered in several countries, is exposed to several human-related threats (Carrete et al., 2010; BirdLife International, 2012; Lambertucci et al., 2011, 2012). Poisoning, including lead contamination, and persecution are among the main threats to which condors are exposed (Ferguson-Lees and Christie, 2001; Lambertucci et al., 2011). It is therefore plausible that they are at higher risk in their foraging areas due to those threats. However, some human disturbances in the breeding areas have also been observed (Lambertucci and Speziale, 2009).

2.2. Study area

We worked in the southern tip of South America (36–44°S, 69–73°W, Fig. 1), central Patagonia (Argentina and Chile). This area consists of a gradient that encompasses two major biogeographic units, the austral forest and the steppe (from west to east), including the transition region referred to as the forest–steppe ecotone (León et al., 1998). Ecotone and steppe areas have been used for extensive livestock ranching since the last century and they currently hold large numbers of alien mammal herbivores (Brown et al., 2006; Speziale et al., 2012). Condors use the area to feed mainly on domestic and wild herbivores (Lambertucci et al., 2009). A very low proportion of the steppe biome is protected (about 4%), with <1% being National Park (Brown et al., 2006). The west (both the Argentine and Chilean slopes of the Andes) is dominated by woodlands with a large number of cliffs that may be used for breeding. This latter biome is relatively well-protected in Chile and very well-protected in Argentina (10% and 34% of its total surface area, respectively) (Brown et al., 2006; Lara et al., 1996).

2.3. Bird tagging and data collection

During austral spring 2010 and 2011, twenty adult Andean condors (11 females and 9 males) were trapped with baited cannon net traps around the city of Bariloche. Birds were fitted with GPS tags (10 birds with patagial PTT-100 50 g Solar Argos/GPS tags, Microwave Telemetry Inc., and 10 with backpack 100 g Solar GPS–GSM CTT-1070-1100 tags, CellTrack Tech.). GPS tags were duty cycled to transmit every day from dawn to dusk at the maximum interval allowed by the unit (every 60 min for PTT tags, and every 15 min for CTT tags). Those tags collected data points corresponding to the coordinates through which each bird passed every day, throughout the months.

Condors were monitored continuously after release. To standardize the monitoring periods, we restricted our analyses to the first six months of monitoring of each bird. Because all the captures were done in spring, this period corresponds to spring-autumn. We obtained 49,022 GPS fixes from the 20 tagged breeding adult condors. All of those fixes were used to determine the land areas covered by the condors regarding their location by country, province, municipality, habitat and protected area size and IUCN category (Categories: (Ia) strict nature reserves, (Ib) wilderness area, (II) National Park, (III) natural monument or feature, (IV) habitat/species management area, (V) protected landscape/seascape; and (VI) protected area with sustainable use of natural resources; (Dudley, 2008)). We also used the fixes to locate breeding and foraging areas, and to estimate distances flown and home ranges.

2.4. Data analyses

Home ranges were calculated as the minimum convex polygons projecting all the fixes into ArcGIS 9.3© and ArcView 3.2© (ESRI Inc., USA). The distance flown each day by a condor was estimated from the sequential straight-line distance between fixes for each day.

Some birds visited both Argentina and Chile, and thus the time spent by the birds in each country was estimated using the selection by location feature of ArcGis 9.3©, as the number of fixes and days within each country. In order to count the number of times the international border was crossed, we first created a 4-km buffer area on each side of the international boundary. We then considered birds to have crossed this international border if they crossed the buffer zone. This was done to avoid the inclusion of data from birds that were flying close to the limit but without crossing it for more than a few kilometres. We chose this buffer since it corresponds to the area surrounding the nest in which condors may be flying while they are in the breeding area, and because some birds were nesting close to the international border and crossed it frequently. We assumed that when they flew more than this distance, it was because the bird was leaving the area.

Breeding areas were determined by the distribution pattern of fixes (coordinates), as the places with the highest concentration of dots in an area of 2-km radius, and were then corroborated in the field. We calculated the number of breeding areas inside protected areas by counting all the nesting areas that fell within the polygon of all the national protected areas in the region. We estimated the time that a bird was foraging outside protected areas first by projecting all data points of the twenty birds that fell within the polygon corresponding to the steppe area. We then estimated the proportion of data points that fell within the steppe biome, and at the same time outside of protected areas. The steppe was a good surrogate of the foraging area since condors do not eat in woodlands; we have observed dozens of carcasses consumed by condors and all of them were located in the steppe and GPS data showed that condor fixes are dispersed and birds spend time on the ground almost exclusively in the steppe.

3. Results

Taken together, all tagged condors flew over an area of 90,843 km^2, and the maximum flight distance for a bird was

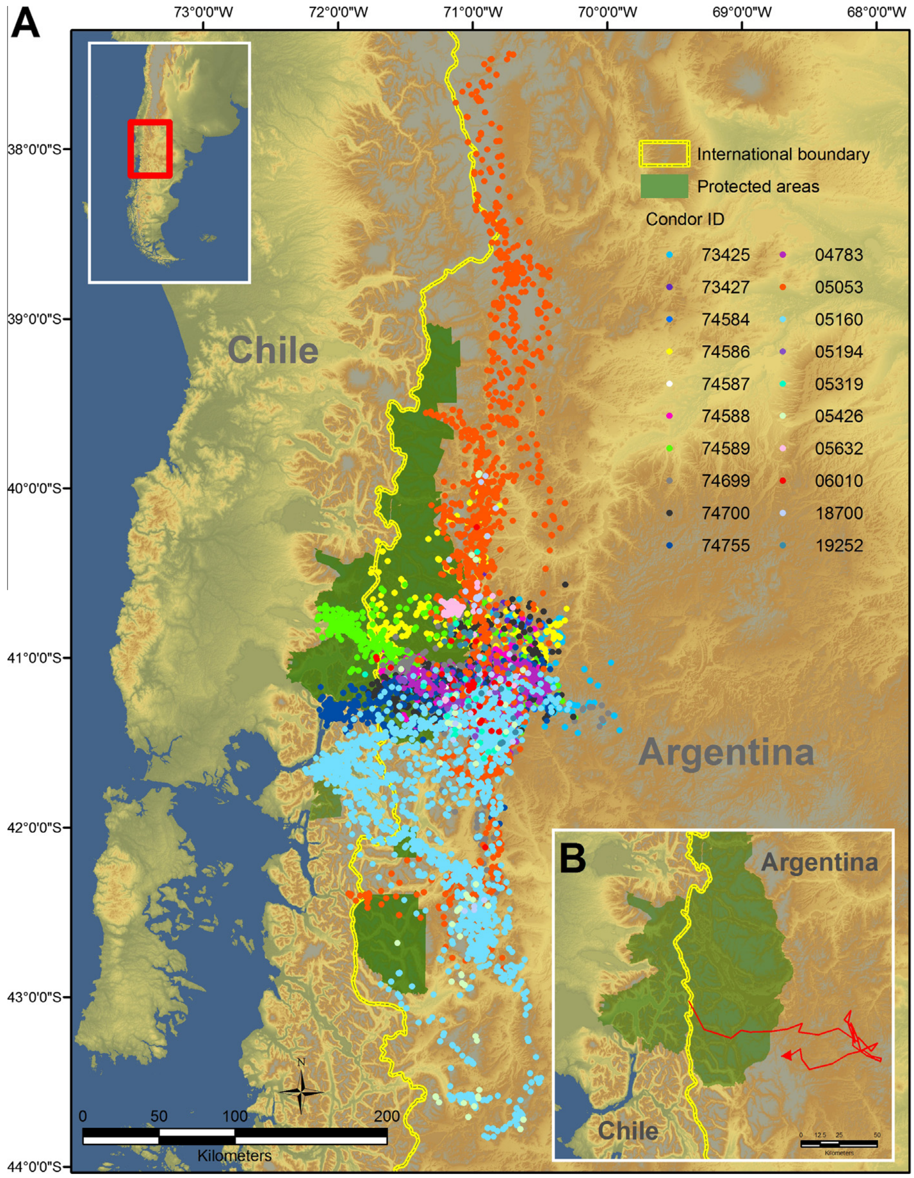

Fig. 1. (A) Movement patterns of 20 GPS-tagged Andean condors in north-west Patagonia (dots). Coloured dots represent different individuals. The yellow line represents the international border. Protected areas are in green. Breeding areas are the sites with high concentrations of dots close to the international border, and feeding areas are the zones with diffuse distribution of dots to the east (see methods). Inset graph (B) detail of the longest one-day trip recorded (349.5 km). The bird departed in the morning from the breeding area close to the international border in Chile (inside a national protected area), crossed the Andean range to Argentina and went to the steppe to forage (inside private lands); then returned to the Andean piedmont for night roosting.

349.5 km/day (Fig. 1). The maximum home range registered for an individual was 53,254 km^2 and the mean daily distance for the bird that flew the most was 152.3 km/day (see online Appendix Table A1). Every day condors crossed different biomes and environments such as woodlands, high Andean vegetation, scrublands and steppes. The studied individuals flew over seven National Parks within two countries, which in total protect an area of more than 1,800,000 hectares (Table 1), but they were not sufficiently large to meet the condors' movement requirements; most of the foraging movements in fact were concentrated in private lands on the Argentinean side of the Andes (Fig. 1).

Most of the marked condors bred inside protected areas (80% of the tagged birds), but foraged outside of those areas (a mean of 90.5% of the foraging time for all birds, and up to 99.8% of the time for the bird that spent the most time in the steppe). The breeding areas of all the tagged birds where within the Andean range both on the Argentinean and Chilean slopes of the Cordillera, but all the birds foraged exclusively in the eastern piedmont (Argentina; Fig. 1). Nine birds visited Chile, three of them made only some short trips close to the international border (<13% localizations in Chile), but the other six birds with a higher frequency of locations in Chile (>43%) bred there on the western slope of the Cordillera (Fig. 2). Movements of those birds involved the crossing of the Andean range on a daily basis (i.e., each bird breeding in Chile crossed the international border a mean of every 1.3–3.0 days depending on the bird, an approximate mean of one cross every 2 days for all birds) with up to two international crosses per day at altitudes of up to 2952 m asl (see online Appendix, Fig. A1).

4. Discussion

Long-distance daily movements, not related to dispersal processes and migration, have been scarcely considered when shaping trans-jurisdictional conservation strategies for threatened vertebrate populations, however, there is an increasing interest in this

Table 1
Land areas in Argentina and Chile used by 20 GPS radio-tagged Andean condors.

Lands	Category (IUCN)[a]	Country	Size (ha)	Provinces (number)	Municipalities	Habitat
Nahuel Huapi	National Park (II and VI)	Argentina	712,160	Neuquén and Río Negro (2)	Several	Woodland, ecotone
Lanín	National Park (II and VI)	Argentina	412,000	Neuquén (1)	Several	Woodland, ecotone
Arrayanes	National Park (II)	Argentina	1753	Neuquén (1)	One	Woodland
Los Alerces	National Park (II and VI)	Argentina	259,570	Chubut (1)	Several	Woodland, ecotone
Limay	Protected landscape (V)	Argentina	50,000	Río Negro (1)	One	Ecotone steppe
Llao Llao	Municipal reserve (IV)	Argentina	1225	Río Negro (1)	One	Woodland
Puyehue	National Park (II)	Chile	107,000	Ranco and Osorno (2)	Several	Woodland
Vicente Perez Rosales	National Park (II)	Chile	253,780	Llanquihue (1)	Several	Woodland
Hornopiren	National Park (II)	Chile	48,232	Palena (1)	One	Woodland
Private lands	Non protected area	Argentina/Chile	>1,000,000	Neuquén, Río Negro, Llanquihue, Ranco and Osorno (5)	Several (>100)	Woodland, ecotone, steppe

[a] IUCN categories: (Ia) strict nature reserves, (Ib) wilderness area, (II) National Park, (III) natural monument or feature, (IV) habitat/species management area, (V) protected landscape/seascape, and (VI) protected area with sustainable use of natural resources (Dudley, 2008).

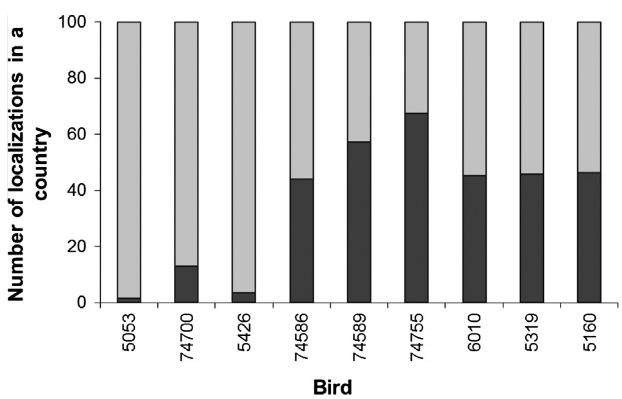

Fig. 2. Proportion of localizations (%) in Argentina (grey) and Chile (black) of the nine Andean condors fitted with satellite tags (from the 20 tagged birds) that crossed the international border (total data localizations, $N = 23,987$).

area of research in relation to marine ecosystems (Yorio, 2009; Block et al., 2011). Here, we show that the conservation of an apex avian scavenger urgently calls for new transboundary conservation strategies in view of their outstanding movement ecology. We found that Andean condors cross the international border between two countries (Argentina and Chile) on a daily basis. Extreme cases are those individuals breeding in a country on the western slope of the Cordillera and using remote areas in another country to obtain food resources. Therefore, for species with such wide home ranges and patterns of daily movements, international and national transboundary policies should take into account the variability in individual spatial ecology strategies, without which the preservation of the entire population would be put at risk.

Species that present large daily movements across political borders require different conservation approaches than species that may move over large distances but do so seasonally, such as migratory birds. Many species move large distances when migrating, and therefore seasonal migratory conservation corridors are proposed as a strategy to protect them (Block et al., 2011; Milner-Gulland et al., 2011). Transboundary movements may be common in marine ecosystems because land and nearby water often fall under different political jurisdictions (Yorio, 2009). In some cases, marine bird species tend to cross different political boundaries every day when moving from breeding to foraging areas, which implies that they can be affected by different human-related impacts in a single day. Indeed, marine protected areas have not been sufficient to protect these species and management actions beyond those reserve areas are needed (Yorio, 2009). In terrestrial ecosystems, some species such as large carnivores (e.g., wolves) may also require transboundary conservation programs given their large home ranges (Falcucci et al., 2013). Indeed adults from different terrestrial species move daily from breeding to foraging areas, but the two areas are generally in close proximity. We show that condors breed at great distances from foraging areas, implying a need to move very large distances every day. Moreover, they must cross an international border on a daily basis in order to feed, which is, to our knowledge, the first report of this behaviour for a terrestrial species.

Daily movements expose animals to changing environmental conditions and to threats according to large-scale variability in biomes and regimes of land protection. Condors behave differently in each country, which implies varying conservation problems and the need for different strategies. We found that condors are breeding in both countries and that several nests are located within protected areas. However, they forage mostly outside reserves, in the piedmont steppe where high numbers of livestock are available. Reserves in the study area have been created with a double purpose of woodland conservation (woodlands are associated with both sides of the Cordillera), but also with a geopolitical aim of consolidating the international border (Brown et al., 2006). As a result the high mountains, which represent the international border between Argentina and Chile, and the woodlands, are well protected. However, the transition zone to the steppe, and the steppe itself, has been overlooked. Only less than 1% of the steppes where condors gather to forage is under actual protection, and is dominated by private farms that do not ensure serious control or management practices for wild species (Brown et al., 2006; Lambertucci et al., 2009). As a result, reserves are not successfully protecting the species.

In particular large scavengers are threatened worldwide, and some species that were very abundant in the past are now close to extinction (Markandya et al., 2008; Ogada et al., 2012; Baral et al., 2013). Those species provide valuable ecosystem services related to carcass consumption (Ogada et al., 2012). Condors are providing this service mainly on private lands in this zone, but at the same time they are exposed to several threats in those areas. Direct and indirect poisoning, contamination with lead, persecution, and competition, are among the main threats that condors may face (e.g., Carrete et al., 2010; Lambertucci et al., 2011, 2012). Although there is little information on the mortality rate of this bird (Lambertucci et al., 2013), there has been some observations of dead animals mostly in our study area, suggesting that most birds die outside of protected areas, on private lands (authors' unpublished data). Some disturbances in breeding areas exist (Lambertucci and Speziale, 2009), but their impact is probably lower than those suffered in the foraging areas.

The fact that this species can cross physical and political barriers brings to light that common policies and strategies are clearly needed (Abbitt et al., 2000; Wilcove and Wikelski, 2008; Block et al., 2011; Hawkes et al., 2011). For instance, high mountain ranges are often natural frontiers for human and animal populations. However, we found that condors were passing over the Andes Mountains when crossing between the two countries. Mountains are not necessarily an insurmountable barrier, but they imply higher costs of transport (Rees, 2004; Hawkes et al., 2011). Therefore, detailed information on the movement patterns and the costs at various scales should be obtained to build sound conservation strategies (Wilcove and Wikelski, 2008). This is particularly important for large soaring vultures who have large movement capacities, are facing special conservation concerns and are key in providing ecosystem services (Markandya et al., 2008; Nathan et al., 2012; Ogada et al., 2012). Since new technology allows the collection of more and better movement data, new and unpredicted movements are being discovered (Hawkes et al., 2011; Klaassen et al., 2011), demonstrating that efforts aimed at protecting these species are insufficient or are not appropriately targeted.

5. Conclusion

An increasing knowledge of life-history patterns and, in particular, the ecology of movement of threatened populations adds new challenges to animal conservation strategies (Holyoak et al., 2008). Our study highlights that the preservation of wide-ranging organisms performing large daily movements, in this case, apex scavengers, may require common international strategies under schemes other than those previously considered (Wilcove and Wikelski, 2008; Block et al., 2011). Our results also highlight that strategies should focus on individual-level approaches integrating intrinsic (e.g., reproductive and foraging behaviour) and extrinsic (e.g., political and geomorphological boundaries) factors able to shape movement ecology (Tibbets and Dowling, 1996; Martin et al., 2007; Holyoak et al., 2008; Milner-Gulland et al., 2011).

A combination of approaches is needed for the conservation of these types of wide ranging species such as the creation of large protected areas and the implementation of specific local strategies. A promising strategy is the implementation of international reserves working under common criteria, such as the Andean North-Patagonian Biosphere Reserve between Argentina and Chile, which covers 4,588,167 hectares. Similar examples that include transboundary reserves exist in other countries (e.g., Parque Internacional La Amistad, between Costa Rica and Panama, with 401,000 hectares), and can be very useful in conserving species that move across international borders. Nonetheless, those huge areas are not sufficient to cover the complete daily movements of some species such as condors. Local conservation strategies are also needed such as collaboration with private land-owners. This is particularly important in countries with large proportions of privately owned lands (e.g., >80% in Argentina) and for the species that depend on them. Policies should also acknowledge the particularities of the species to be protected considering different behaviours (i.e., needs differ between breeding and foraging activities) to design efficient conservation strategies. This approach may be valid not only for apex scavengers but also for other large-sized organisms with extreme movement patterns like carnivorous mammals, birds and fish (Gittleman and Harvey, 1982; Yorio, 2009; Block et al., 2011; Louzao et al., 2012; Falcucci et al., 2013). Therefore, our results impose new challenges for cooperative international, regional and local efforts aimed to combine the conservation of flagship species, management of public and private lands and maintenance of valuable ecosystem services.

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Appendix A. Supplementary material

Supplementary material associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2013.12.041.

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