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DEFINING SPATIAL CONSERVATION PRIORITIES FOR THE ANDEAN CONDOR (*VULTUR GRYPHUS*)

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Abstract.—The Andean Condor (*Vultur gryphus*) is a culturally iconic wildlife symbol for the South American Andes, but is naturally found at very low population densities, and is increasingly threatened. Using the Range Wide Priority Setting methodology, we (a group of 38 Andean Condor experts) updated the Andean Condor historical range (3,230,061 km^2), systematized 9998 Andean Condor distribution points across the range, and identified geographic areas for which there was expert knowledge (66%), including areas where Andean Condors no longer occur (7%), and geographic areas where condors are believed to range, but for which there was not expert knowledge about condor presence (34%). To prioritize conservation action into the future and identify existing Andean Condor population strongholds, we used expert knowledge to identify 21 of the most important areas for the conservation of the species (i.e., Andean Condor Conservation Units [ACCUs]) that cover 37% of the revised historical range, and range in size from 837 km^2 to 298,951 km^2. In general, ACCUs were relatively small in the northern portion of the range in Venezuela, Colombia, Ecuador, and northern Peru, and significantly larger in the central and southern portion of the range in Peru, Bolivia, Chile, and Argentina, reflecting the reduced and narrower historical range in the northern portion of the range, as well as increased threats. Andean Condors can fly extremely long distances and so the populations of many neighboring ACCUs are probably still functionally connected, although this situation also underlines the need for integrated and large-scale conservation efforts for this species. As a function of the Range Wide Priority Setting results, we make recommendations to ensure population connectivity into the future and engage a wide range of actors in Andean Condor conservation efforts.

Key Words: *Andean Condor*; Vultur gryphus; *conservation*; *Range Wide Priority Setting*.

DEFINICIÓN DE LAS PRIORIDADES ESPACIALES DE CONSERVACIÓN DE *VULTUR GRYPHUS*

Resumen.—El cóndor andino *Vultur gryphus* es un símbolo de vida silvestre culturalmente icónico para los Andes sudamericanos, pero se encuentra naturalmente en densidades poblacionales muy bajas, y está cada vez más amenazado. Utilizando la metodología de Establecimiento de Prioridades de Conservación a lo largo

de su Distribución, nosotros (un grupo de 38 expertos en *V. gryphus*) actualizamos el área de distribución histórica de la especie (3.230.061 km^2), sistematizamos 9998 puntos de distribución en toda su área de distribución, e identificamos las áreas geográficas para las que había conocimiento experto (66%), incluyendo las áreas en las que *V. gryphus* ya no está presente (7%), y las áreas geográficas en las que se cree que se distribuye, pero para las que no había conocimiento experto sobre su presencia (34%). Para priorizar las acciones de conservación en el futuro e identificar los bastiones poblacionales existentes de *V. gryphus*, utilizamos el conocimiento experto para identificar 21 de las áreas más importantes para la conservación de la especie (es decir, Unidades de Conservación del Cóndor Andino [ACCU, por sus siglas en inglés]), que cubren el 37% del área de distribución histórica, y tienen un tamaño de 837 km^2 a 298.951 km^2. En general, las ACCUs fueron relativamente pequeñas en la porción norte del área de distribución en Venezuela, Colombia, Ecuador y el norte de Perú, y significativamente más grandes en la porción central y sur del área de distribución en Perú, Bolivia, Chile y Argentina, reflejando la reducción y el estrechamiento del área de distribución histórica en la porción norte de su area de distribución, así como el aumento de las amenazas. *V. gryphus* puede volar distancias extremadamente largas, por lo que es probable que las poblaciones de muchas ACCUs vecinas sigan estando conectadas funcionalmente, aunque esta situación también subraya la necesidad de esfuerzos de conservación integrados y a gran escala para esta especie. En función de los resultados del establecimiento de prioridades en toda el área de distribución, hacemos recomendaciones para asegurar la conectividad de la población en el futuro y para involucrar a una amplia gama de actores en los esfuerzos de conservación de *V. gryphus*.

[Traducción de los autores editada]

INTRODUCTION

The Andean Condor (*Vultur gryphus*) is an emblem of the Andean region and plays essential cultural and ecological roles in Andean ecosystems. The Andean Condor is found on both sides of the Andean Mountain range, from Venezuela to Patagonia (Birdlife International 2020). Condors are apex scavengers that are able to open large carcasses (Lambertucci et al. 2018), thereby speeding up decomposition processes, and probably decreasing risks of disease from carrion (Ogada et al. 2012). Condors are among the longest-lived bird species and are particularly vulnerable to extinction due to their naturally low abundance, wide-ranging behavior, late age of maturity, and low reproductive rate (Lambertucci 2007, Houston et al. 2020).

Ongoing and persistent threats that impact Andean Condor populations range from habitat destruction, especially relevant for roosting and nesting sites, to hunting due to perceived and documented human-wildlife conflicts (Naller et al. 2008, Ministerio del Ambiente and The Peregrine Fund 2018). Documented threats (Pavez and Estades 2016) also include collisions with power line infrastructure, an extremely worrying increase in illegal carcass poisoning for predator control (Alarcón and Lambertucci 2018), secondary lead poisoning due to consumption of hunted prey species (Wiemeyer et al. 2017), use of body parts in handicrafts, collisions with vehicles (Speziale et al. 2008), competition for food from feral and domestic dogs, tourism disturbance, and use in folkloric Yawar Fiesta events in Peru, often resulting in serious injury or death (Piana 2019).

The global Andean Condor population has been proposed at 10,000 birds, including 6700 mature individuals (Birdlife International 2020), although there are no rigorous population estimates with confidence limits across the majority of its distribution. Andean Condors have been virtually extirpated from the northern portion of their range with fewer than 300 adults now patchily distributed across Ecuador, Colombia, and Venezuela (Sáenz-Jiménez et al. 2014, Naveda-Rodríguez et al. 2016, Vargas et al. 2018), where reintroductions have been underway for more than a decade. In the central Andes, recent efforts in Bolivia have estimated a total population size of 1388 individuals (Méndez et al. 2015, 2019), and in a portion of Peru, between 155 and 249 individuals were estimated (Piana and Angulo 2015). Population estimates of about 2000 individuals have been suggested for both Argentina and Chile (World Wildlife Foundation and Fundación Bioandina 2000), although there are no systematic counts in the field to support these estimates, and given the geography of these neighboring elongated countries, it seems probable that there is overlap in the condor population between countries. However, estimates at communal roosts in Argentina and Chile suggest that there are hundreds in each region studied (Feijóo 1999, Kusch 2004, 2006, Lambertucci 2010, Gargiulo 2014).

National Red List classifications for the Andean Condor are as follows: Critically Endangered in Venezuela (Rodríguez et al. 2015, Sharpe et al. 2015) and Colombia (Renjifo et al. 2016); Endangered in Ecuador (Freile et al. 2019), Peru (Decreto Supremo 004-2014-MINAGRI) and Argentina (Argentina Ambiental 2017); and Vulnerable in Bolivia (Balderrama et al. 2009) and Chile (Corporacíon Nacional Forestal 1993). Given these national classifications and the recent increase in the devastating threat of illegal carcass poisoning for predator control, the International Union for Conservation of Nature (IUCN) recently upgraded the global red list classification for the Andean Condor from Near Threatened to Vulnerable (Birdlife International 2020).

There is an urgent need to identify priority conservation areas for naturally scarce wildlife species, especially those with large individual home ranges, and low reproductive rates and genetic variability (Santangeli et al. 2019). This is especially important for species under known and significant threats and that are particularly sensitive to environmental change due to their longevity (Beissinger 2000, Owens and Bennett 2000, Knight and Cowling 2007). Andean Condors are known to use large areas covering a variety of management jurisdictions; studies in Argentina have demonstrated the importance of protected areas in the protection of the species, and some researchers have proposed prioritization of conservation areas based on movement data of satellite-tagged individuals (Lambertucci et al. 2014, Guido et al. 2020, Perrig et al. 2020). However, there is a pressing need for a prioritization of conservation areas across the entire distribution of the species.

The main objective of this work was to inform future multi-national conservation decision-making by systematizing existing distributional knowledge and identifying priority conservation areas for the Andean Condor throughout its distribution. To do so, we selected the expert-driven Range Wide Priority Setting exercise (RWPS), which was developed to systematize scarce and usually dispersed data regarding the overall distribution of globally threatened wildlife species, to make informed management decisions regarding their conservation (Sanderson et al. 2002, Thorbjarnarson et al. 2006, Marieb 2007, Taber et al. 2009, Wallace et al. 2014b).

The result of the RWPS was the report *Saving the Symbol of the Andes: A Range Wide Conservation Priority Setting Exercise for the Andean Condor* (*Vultur gryphus*; Wallace et al. 2020). This manuscript is a summary of that report.

Methods

In 2015, a partnership of the National Forestry and Wildlife Service of Peru, the Peruvian Ministry of Environment, The Peregrine Fund, and the Wildlife Conservation Society launched an Andean Condor Range Wide Priority Setting exercise with 38 experts working with the species in different parts of its distribution.

Prior to an in-person May 2015 workshop, we systematized information about Andean Condor distribution from three sources. Firstly, we collected Andean Condor distribution points derived from a thorough literature review. To do so we gathered information by using key words (Andean Condor, cóndor andino, *Vultur, Vultur gryphus*) to search GoogleScholar™, as well as unpublished reports from Bolivia and Peru, which had been gathered in a previous systematization effort for the central portion of the range (Wallace et al. 2014a). Secondly, we requested all Andean Condor occurrence records from the largest citizen science effort in the world, eBird (https://ebird.org/explore), and downloaded them in May 2015. Finally, we solicited additional unpublished information from Andean Condor experts from different countries using a specific spreadsheet on observed Andean Condor roosts, nests, and feeding sites (Supplemental Material). By comparing the location, date and observer information for distribution points, we eliminated duplicate distribution points arising from more than one source. In the mapping analyses described below, we used all unique distribution points. All current Andean Condor distribution areas were also assumed to be included in the historical distribution.

As part of the RWPS methodology (Sanderson et al. 2002), prior to the workshop Andean Condor experts were also asked to draw polygons describing their knowledge of Andean Condors including: (1) Area of Knowledge (areas where experts are knowledgeable enough to express opinion about the presence or absence of Andean Condors); (2) Proposed Actual Distribution (areas where experts believe the Andean Condor has occurred in the last 20 yr), and (3) Andean Condor Conservation Units (ACCUs; areas perceived by experts to be important strongholds for the long-term conservation of Andean Condor populations within the expert's area of knowledge). Experts received maps of their

country in GoogleEarth™ format as an additional tool with which to draw polygons and/or place distribution points. We processed and combined all information into one Geographic Information System (GIS) using the ArcGIS platform (Version 10.3) and incorporated data on human settlements; international, state and provincial boundaries; and main and secondary roads (DIVA-GIS; https://www.diva-gis.org/Data), as well as satellite images to facilitate recognition of physical characteristics such as mountains, valleys, and plains.

Workshop participants ($n = 101$) were placed into seven geographical working groups: (1) Colombia and Venezuela, (2) Ecuador, (3) northern Peru, (4) southern Peru, (5) Bolivia, (6) Argentina, and (7) Chile. Using printed maps and satellite imagery (http://www.esri.com/software/arcgis/arcgisonline/bing-maps.html) at varying scales depending on the country (from 1:900,000 for Bolivia to 1:5,500,000 for Chile), and digital versions of the same on portable computers, each group was asked to review the historical range of the Andean Condor (Fjeldså and Krabbe 1999). Experts used their collective knowledge about Andean Condors in combination with all systematized distribution points, altitudinal contours for the range, and satellite imagery to define the historical range (where Andean Condors are thought to have occurred since 1900).

The working groups were then asked to review pre-workshop draft maps based on information provided by experts prior to the workshop on the conservation status of the Andean Condor. First, working groups reviewed systematized distribution data divided into historical (1900–1994) and current distribution points (1995–2015). Then the working groups defined places or polygons where experts had knowledge of the condor, ranging from isolated observations, to information on movement data from an individual condor, to the presence of a nest or communal roost, to in-depth ecological knowledge, and distinguished places within the historical range where Andean Condors are known to no longer occur. Working groups also identified places where experts did not have knowledge of either presence or absence of Andean Condors. Finally, working groups proposed ACCUs within their area of knowledge. Groups worked in a systematic order and clearly marked changes on printed satellite image maps and/or digital versions in kmz format (Google Earth™). Neighboring working groups then met to compare, discuss and integrate distribution, knowledge, and ACCU polygons for a number of transboundary areas across the range. Subsequently, maps for the seven working groups were combined into range-wide maps for each category (historical distribution, expert knowledge, no longer occur, without expert knowledge, and ACCUs).

After the workshop, the maps were digitized and modified according to the corrections and proposals of the workshop participants. We then sent the modified maps to the participating Andean Condor experts for review and incorporated any final edits. We divided the ACCUs into three size classes: (1) relatively small ACCUs of $<20{,}000$ km^2, (2) medium-sized ACCUs of 20,001 to $<100{,}000$ km^2, and (3) relatively large ACCUs of $>100{,}000$ km^2. We also calculated the percentage of each ACCU protected by three jurisdictional categories of protected areas: (1) National Protected Areas, (2) State or Regional Scale Protected Areas, and (3) Municipal or Private Protected Areas, by overlapping the ACCUs and protected areas using the clip and intersect tools in ArcGIS.

RESULTS

Historical Range of the Andean Condor. Overall, the revision of the Andean Condor historical range resulted in a polygon of 3,230,061 km^2 (Fig. 1a). This represents an almost 37% increase for the estimated historical range as compared to the previously estimated area of approximately 2,362,397 km^2 (Fjeldså and Krabbe 1990). From this point forward, "historical range" is used to refer only to the 2020 revised historical range map.

Andean Condor Distribution Points. The literature review resulted in a total of 928 distribution points as a baseline prior to the workshop. Andean Condor experts attending the RWPS exercise provided an additional 793 distribution points to the database. After filtering duplicate points from the database, eBird added 8277 distribution points. The overall database of Andean Condor distribution points consisted of 9998 data points (historical 1900–1994: 185 data points; current 1995–2015: 9813 data points). The number of Andean Condor distribution points for each country ranged from 12 distribution points in Venezuela, the northern distributional extreme, to 3863 data points in Chile at the southern extreme (Table 1).

The portion of the species' overall historical range found within each country ranged from $<1\%$ in Venezuela to almost 43% in Argentina. The southern portion of the historical range in Argentina and

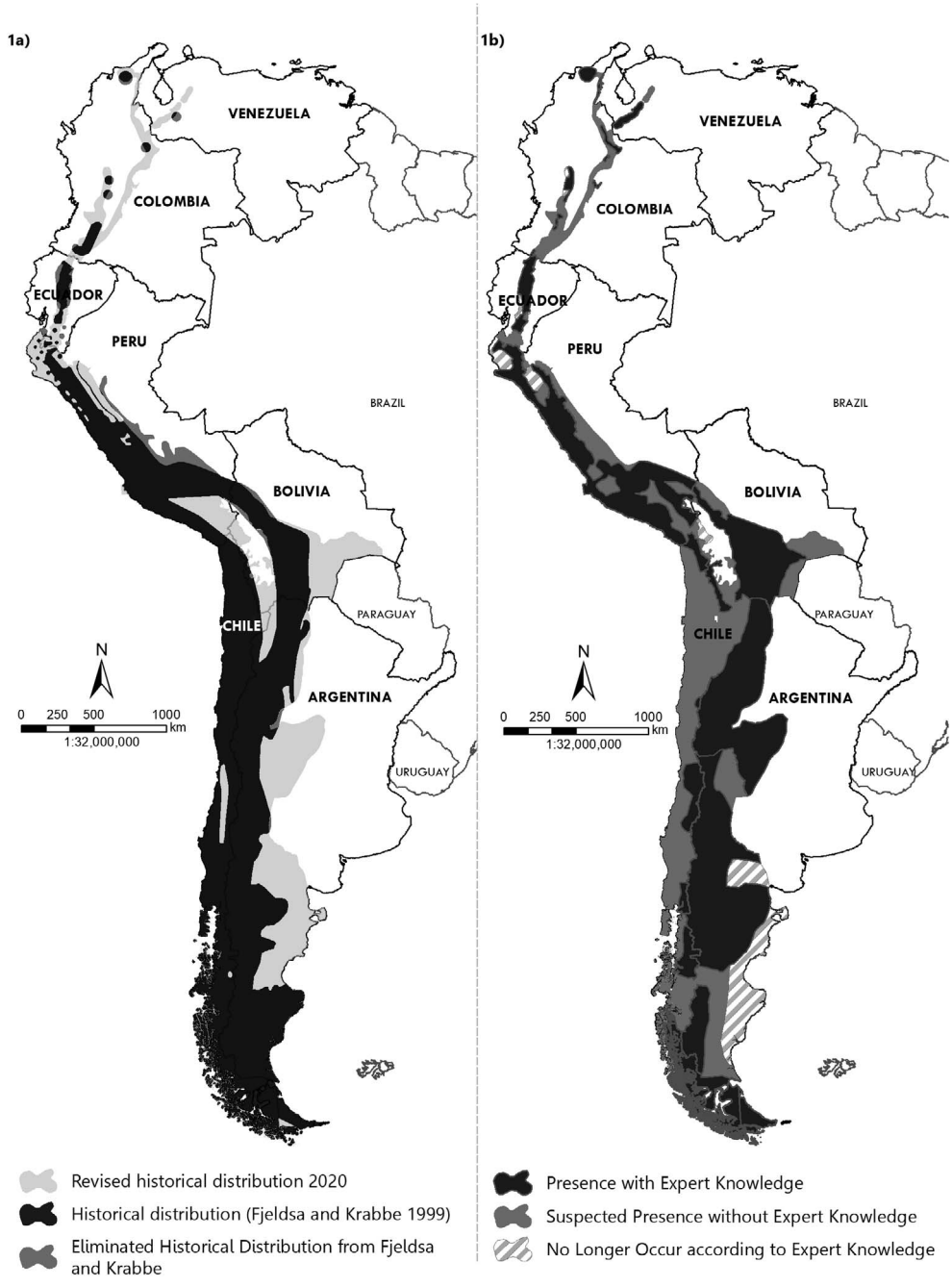

Figure 1. Revised Andean Condor historical range (a) as compared to Fjeldså and Krabbe (1999) previous historical range, and (b) highlighted areas with and without expert knowledge for Andean Condors, and areas where they no longer occur. Figure adapted from Wallace et al. 2020.

Table 1. Andean Condor revised historical range area and distribution points by country (Wallace et al. 2020).

COUNTRY	REVISED HISTORICAL ANDEAN CONDOR RANGE SIZE (km^2)	PERCENT OF REVISED HISTORICAL RANGE	NUMBER OF DISTRIBUTION POINTS USED IN RWPS
Venezuela	17,656	0.55	12
Colombia	129,867	4.02	222
Ecuador	53,831	1.67	1163
Peru	529,097	16.38	939
Bolivia	366,091	11.33	1181
Chile	751,481	23.27	3863
Argentina	1,382,037	42.78	2639
Total	**3,230,061**	**100**	**9998**

Chile accounted for just over 66% of the overall revised historical range. The central portion in Peru and Bolivia represented almost 28%, and the northern portion of the range in Colombia, Ecuador, and Venezuela accounted for just 6% of the historical range (Table 1). The map of distribution points (Fig. 2) reveals a virtually continuous distribution for the Andean Condor in Argentina, Chile, Bolivia, Peru, and Ecuador, with the distribution points then being scarcer and more isolated in Colombia and Venezuela.

Andean Condor Extirpated Areas. Workshop participants identified areas where Andean Condors no longer occur within their historical range (Fig. 1b), amounting to just over 7% of the estimated historical range. These areas consisted of two small polygons in the central Andes of Colombia, a similar-sized polygon in the central portion of the Ecuadorian Andes, three larger polygons in northern Peru from the Pacific to the eastern Andes, one polygon in the Sajama region of Bolivia, and the two largest polygons in southeastern Argentina along the Atlantic coast.

Areas Identified With and Without Andean Condor Expert Knowledge. Andean Condor experts detailed areas with or without expert knowledge (Fig. 1b). Unsurprisingly, the polygon areas with knowledge across the Andean Condor distribution largely reflect known localities (Fig. 2). Overall, experts identified almost 66% of the Andean Condor historical range as either containing Andean Condor populations (59%), or where Andean Condors are now considered absent (7%; Table 2). Experts noted that 34% of the historical range is without expert knowledge (Table 2). Nevertheless, the eBird dataset provided presence data for large portions in the southern part of the range (Argentina and Chile), in areas identified as without expert knowledge or expert-derived distribution points (Fig. 2).

Priority Andean Condor Conservation Units (ACCUs). In total, in the original workshop 31 ACCUs were proposed by Andean Condor experts, covering an area representing 37% of the adjusted historical range. More than half of the area prioritized as ACCUs are in Argentina (51%), slightly more than would be expected based on the portion of the historical range for Argentina (43%; Table 1). Experts also prioritized a larger area in Bolivia (18%) than might be expected based on the percentage of the historical range (11%), whereas in Peru (14%), and particularly Chile (11%), experts prioritized less area than might be expected given the historical range in those countries, 16% and 23% respectively (Tables 1, 3). ACCUs in the northern part of the Andean Condor range (Venezuela, Colombia, and Ecuador) were small (just under 6%) and thus reflect small historical range portions (just over 6%).

Several ACCUs in neighboring countries were immediately adjacent to each other; in the post-workshop analysis we combined several of the original country-specific ACCUs into trans-boundary ACCUs. Once these were combined, the number of ACCUs was reduced to 21 units (Table 4; Fig. 3). Fourteen of the ACCUs (most in Venezuela, Colombia, Ecuador, and northern Peru) were classified as small (Table 4), three as medium, and four as large (three of which are enormous transboundary areas

Table 2. Andean Condor expert knowledge across the revised historical range (Wallace et al. 2020).

POLYGON	TOTAL AREA (km^2)	PERCENT OF REVISED HISTORICAL RANGE
Area with expert knowledge where Andean Condors still occur	1,888,924	58.5
Area with expert knowledge where Andean Condors no longer exist	236,012	7.3
Area without expert knowledge	1,105,125	34.2
Total revised historical Andean Condor range	**3,230,061**	**100.0**

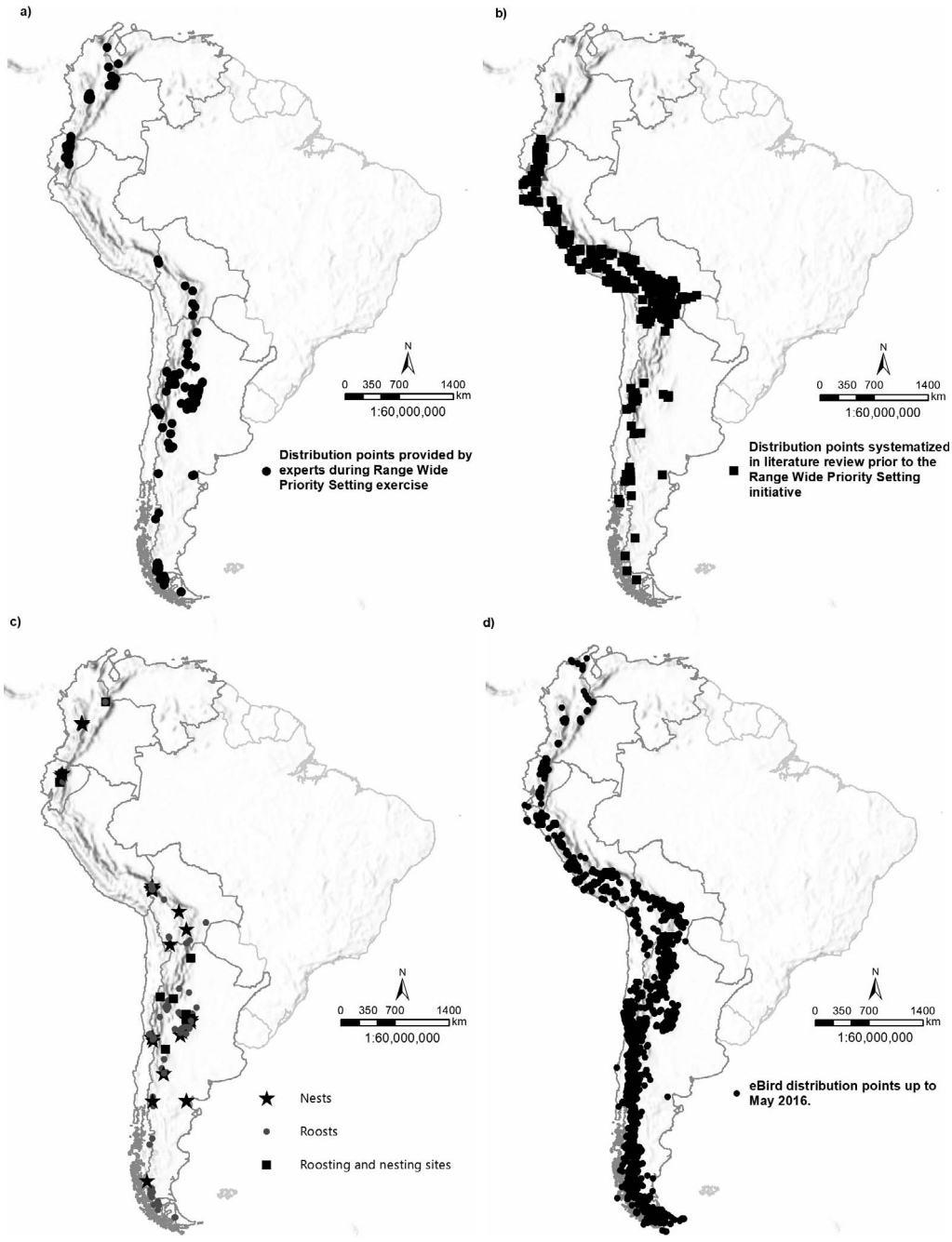

Figure 2. Distribution of confirmed Andean Condor localities obtained from: (a) Andean Condor experts during the Range Wide Priority Setting (RWPS) exercise; (b) a literature review prior to the RWPS; (c) known nesting and roosting sites; and (d) eBird occurrences up to May 2016. Figure adapted from Wallace et al. 2020.

Table 3. Size and area percentage of Andean Condor Conservation Units (ACCUs) by country (Wallace et al. 2020).

COUNTRY	*n*	AREA (km^2) IN ACCUS	% TOTAL CONSERVATION UNIT AREA
Venezuela	2	12,447	1.03
Colombia	8	31,492	2.62
Ecuador	3	22,973	1.91
Peru	5	169,131	14.05
Bolivia	3	213,698	17.75
Chile	5	138,058	11.47
Argentina	6	615,903	51.17
Total area in ACCUs	**31**	**1,203,703**	**100**

of well over 200,000 km^2, one bridging Argentina and Bolivia and two running along the Argentina and Chile border). A total of nearly 16% of the area defined as ACCUs is under formal protection, although there is considerable variation in protection among ACCUs (Table 4), protected percentages varying between 0% to >50% for smaller ACCUs, but mainly well below 20% protection for the medium and large ACCUs (range = 9–30%). Nevertheless, at least 30% of the area of seven of the ACCUs is already protected, although that includes only one of the seven largest ACCUs (Table 4).

DISCUSSION

Andean Condor Historical Range. The historical range update included a major increase in area and the number of observations available, primarily due to records from eBird, and the fact that the spatial information used for this exercise was of considerably better quality and finer scale because of the advent of GIS technology and increased availability of satellite images. This updated species global distributional range totals 3,230,061 km^2 and represents an important perspective with which to set future conservation targets, as well as measure changes in the species' distribution. The Andean Condor has an extremely linear distribution along the Andes (Fjeldså and Krabbe 1999, Houston et al. 2020), which might make it more prone to range fragmentation and loss of gene flow.

Expert Knowledge Coverage within the Andean Condor Historical Range. The Andean Condor experts felt comfortable expressing their opinion about Andean Condor presence in almost 59% of the revised historical range and absence in 7% of the revised historical range. This amounted to a total knowledge coverage of 66%, or almost two-thirds of

Table 4. Final list of Andean Condor Conservation Units (ACCUs; Wallace et al. 2020).

ACCU#	COUNTRY	ACCU NAME	AREA (km^2)	TOTAL % PROTECTED
1	Venezuela	Cordillera de Mérida	11,870	39.0
2	Venezuela and Colombia	Serranía del Perijá	3068	17.7
3	Colombia	Sierra Nevada de Santa Marta	9289	55.9
4	Colombia	Páramos de los Andes Nororientales	5593	32.1
5	Colombia	Corredor de Páramos Guantiva-La Rusia-Iguaque	837	7.7
6	Colombia	Chingaza	1381	57.8
7	Colombia	Los Nevados	8542	9.5
8	Colombia	Puracé	2487	46.6
9	Colombia and Ecuador	Chiles-Llanganates	13,349	33.6
10	Ecuador	Sangay National Park	3220	55.6
11	Ecuador	Azuay-Loja-El Oro	7278	3.7
12	Peru	Andes de Piura-Lambayeque	8125	0
13	Peru	Illescas	1813	0
14	Peru	Andes Centrales de Perú	66,131	9.2
15	Peru and Bolivia	Sur de Perú-Norte de Bolivia	97,017	10.9
16	Bolivia	Lípez-Sillillica	17,538	30.6
17	Argentina and Bolivia	Cordillera Oriental-Sierras Subandinas-Sierras Pampeanas	298,951	16.5
18	Argentina and Chile	Andes Centrales-Sierras Pampeanas	215,079	12.1
19	Argentina and Chile	Patagonia Norte	237,784	12.9
20	Argentina	Somuncurá	53,187	30.1
21	Argentina and Chile	Patagonia Sur	141,167	15.9

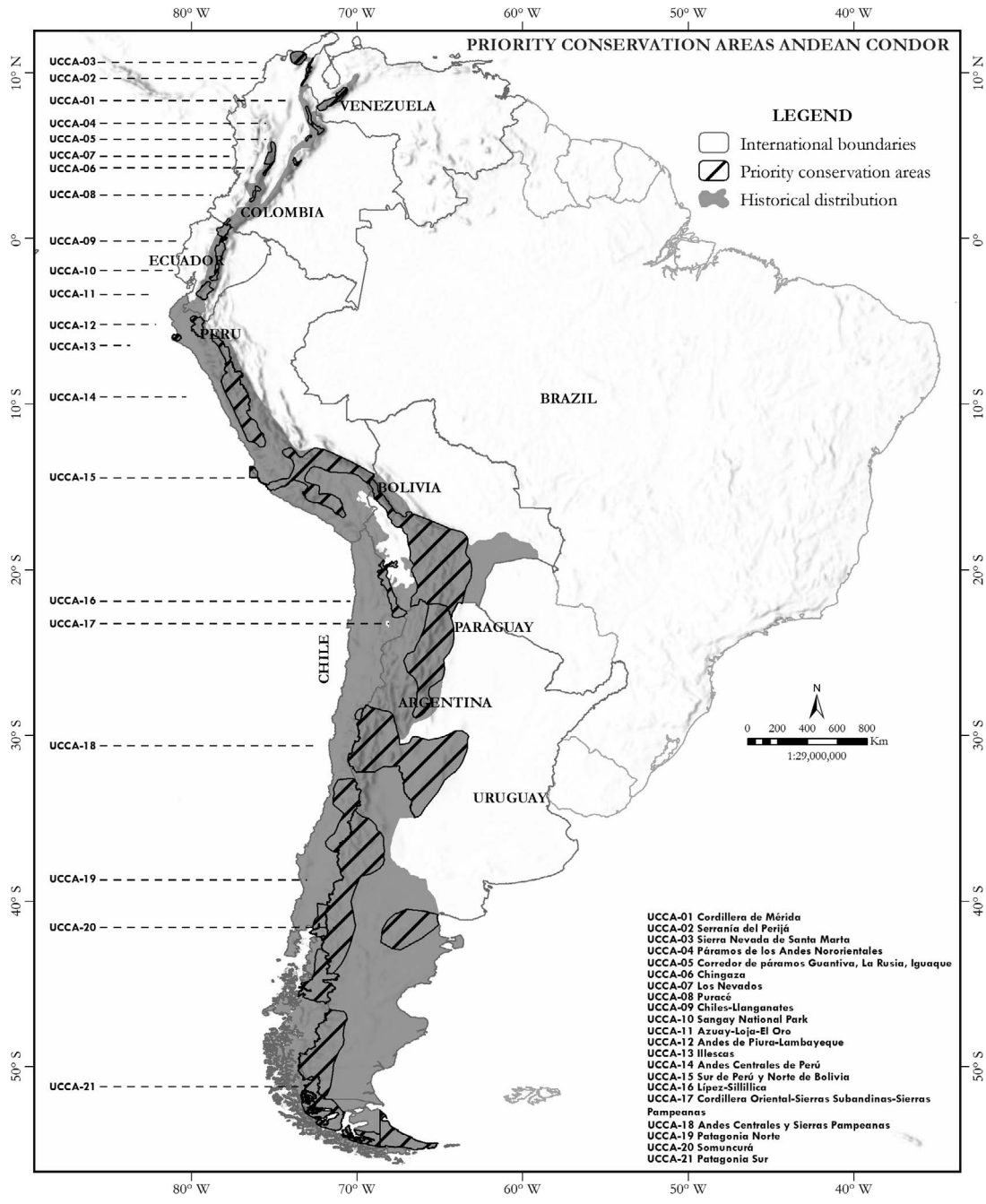

Figure 3. Priority Andean Condor Conservation Units (UCCA in Spanish) across the range in South America. Figure adapted from Wallace et al. 2020.

the historical range. Nevertheless, in all countries, there were significant areas without expert knowledge about Andean Condors, totaling 34% of the historical range (notably in Bolivia, Peru, and Chile). In addition, many areas with expert knowledge were limited to Andean Condor observations and lacked detailed ecological or population information.

Expert knowledge coverage of 66% is lower than other iconic species previously considered in complete RWPS exercises in the region. For example, the original jaguar (*Panthera onca*) RWPS analysis revealed expert knowledge areas covered 83% of the historical range (Sanderson et al. 2002), which increased in 2006 to 96% (Marieb 2007). For less cryptic species, expert knowledge covered 99% of the historical range for white-lipped peccaries (*Tayassu pecari*) and almost 100% for lowland tapirs (*Tapirus terrestris*; Taber et al. 2009). However, expert knowledge coverage was just 58% for Andean bears (*Tremarctos ornatus*) in Bolivia and Peru (Wallace et al. 2014b), which also have an exceptionally linear distribution that is largely confined to the eastern slopes of the Andes Mountain range from Venezuela to Bolivia.

In the northern and central portions of the range there was considerable overlap and agreement between expert-driven knowledge and available eBird data. However, in the southern portion of the range, especially in Chile, large areas were identified as areas without expert knowledge, but were populated with significant concentrations of Andean Condor observations from eBird (Fig. 2d). Future studies in Chile should verify locations with high densities of citizen science observations.

Andean Condor Actual Range. Workshop participants identified eight polygons where Andean Condors are considered to have been extirpated: two in central Colombia, one in south-central Ecuador, two in northern Peru, one in western Bolivia, and two in southeastern Argentina, accounting for 7% of the revised historical range. Given that 34% of the revised historical range has no knowledge coverage from participating experts, the need for further expert participation and/or fieldwork is evident and pressing. Thus, current knowledge suggests that Andean Condors remain present in at least 59% of their historical range, although this increases to around 80% when incorporating eBird knowledge (Fig. 2d). Serious threats, such as large poisoning events with pesticides (Alarcón and Lambertucci 2018, Estrada Pacheco et al. 2020) and lead (Wiemeyer et al. 2017), in combination with confirmed local extirpations herein, underscore the need for species-specific conservation planning and actions.

In comparison to tapirs, peccaries, and jaguars in South America, all of which have been extirpated from between 14 and 39% of their historical range (Marieb 2007, Taber et al. 2009), the 7% value for condors is encouraging. However, in this work we only evaluated the presence of individuals, and we do not know their regional abundances, their demographic composition or ability to breed, or their ability to perform historical behaviors, such as foraging movements (Lambertucci et al. 2012, 2018). Andean Condors have overlapping individual home ranges, which are also orders of magnitude larger (Lambertucci et al. 2014) than those of tapirs (Medici 2011), white-lipped peccaries (Moreira-Ramírez et al. 2019), or jaguars (Morato et al. 2016), and many condors can be vulnerable to threats in a relatively small area. Therefore, the percentage of historical range where Andean Condors are still observed as a standalone indicator of the conservation status of this species may not be appropriate.

Andean Condor Conservation Units (ACCUs). Andean Condor experts proposed a total of twenty-one ACCUs from western Venezuela to Tierra del Fuego, which may represent the best hope for the long-term conservation of Andean Condors across the actual range. The ACCUs cover 37% of the estimated actual range of the species. Experts defined ACCUs ranging from relatively small areas of just 837 km^2 (Corredor de Páramos Guantiva-La Rusia-Iguaque) to massive areas of up to 298,951 km^2 (Cordillera Oriental-Sierras Subandinas-Sierras Pampeanas; Table 4). These immense areas highlight the need for an integrated and landscape-level approach for Andean Condor conservation involving a diversity of jurisdictions and associated local stakeholders.

In general, ACCUs are relatively small in the northern portion of the Andean Condor range (Venezuela, Colombia, Ecuador, and northern Peru), and an order of magnitude larger in the central and southern portion of the range (central and southern Peru, Bolivia, Chile, and Argentina), which to a degree reflects the pattern of the historical distribution of the species. Several of the smaller ACCUs are almost certainly not large enough to permanently hold viable populations of Andean Condors, given the birds' exceptionally

large ranging patterns (Lambertucci et al. 2014). However, within the framework of a regional analysis for a wide-ranging species, these sites are important as they have known roosting, nesting, and feeding sites (Lambertucci 2010, Perrig et al. 2020). Thus, recognition of these critical sites in the northern portion of the range, where Andean Condors are especially threatened, is an important step forward in conservation planning for the species. Designating movement corridors as priority areas for conservation may be less important for Andean Condors than terrestrial animals due to their capacity for rapid travel across huge home ranges (Lambertucci et al. 2014) and resulting low genetic variability (Hendrickson et al. 2003, Padro et al. 2018).

The medium and large ACCUs in the central and southern portions of the historical range may well be large enough to permanently hold meaningful populations of Andean Condors. However, the ACCUs' immense sizes underline the need for integrated conservation approaches that embrace the importance of including different types of protected areas (e.g., international biosphere reserves; Guido et al. 2020) and also going beyond protected area limits and engaging in discussions and management practices with a wide range of local stakeholders and communities. It is also worth stressing that given the flying capacity of Andean Condors, populations of many neighboring ACCUs are probably still functionally connected. Nonetheless, establishing longer-term connectivity through strategic management activities should be considered, especially for the smaller ACCUs.

Currently, 14% of the Andean Condor's historical range is under formal protection. This does not meet the 17% recommended by the Convention on Biological Diversity as a 2011–2020 goal in the Aichi targets (Convention on Biological Diversity 2011). It is important to emphasize that individual Andean Condors travel huge distances, and the ranges of most individuals in the global population include protected areas, but also large portions of other unprotected types of land management (Lambertucci et al. 2014, Guido et al. 2020). The protected portions of the ACCUs were deemed to be especially important for nesting and roosting. However, given that adult mortality is thought to be the most important driver of population rate change in Andean Condors, on-the-ground conservation efforts should focus on changing human behavior in condor foraging areas, which concentrate many of the most important threats such as poisoning (Lambertucci et al. 2014, Naveda-Rodríguez et al. 2016, Guido et al. 2020, Perrig et al. 2020). Thus, as for Old World vultures (Santangeli et al. 2019), the challenge into the future will be to secure the sustainable and effective management of the protected areas, as well as to effectively achieve conservation outside of protected areas within the ACCUs.

In summary, the results demonstrate a clear pattern reflected across the historical range, current range, as well as identified ACCUs. The areas from the northern portion of the historical range are significantly smaller and substantially more fragmented than in the central range, and especially the southern portion of the range (Fig. 3). This pattern is also reflected in terms of known data regarding Andean Condor populations, with numbers in Venezuela, Colombia, and Ecuador particularly low as compared to Peru, Bolivia, Chile, and Argentina. The RWPS exercise amassed almost 10,000 distribution points and this data set, along with the associated polygons, provides a means of monitoring the conservation status of Andean Condors across the range into the future. Indeed, as satellite telemetry studies increase, the possibility of incorporating an even richer data set regarding condor flight paths, roosts, nests, and foraging sites into conservation decision-making processes (Perrig et al. 2020) will allow further refinement of these analyses.

Next Steps and Recommendations. Based on the results of this Range Wide Priority Setting exercise for the Andean Condor, we propose the following priority recommendations: (1) develop specific and comprehensive analyses and conservation plans with integrated and diverse conservation actions for identified ACCUs; (2) conduct surveys regarding the presence of Andean Condors in areas without expert knowledge about the species, or with very poor knowledge within existing ACCUs; (3) design and apply standardized Andean Condor census methodologies using examples from Bolivia, Chile, Ecuador, Argentina, and Peru, but also other monitoring techniques (e.g., Perrig et al. 2019). These standardized methodologies should then be applied across the range, to assess population size, especially at priority conservation sites, thereby better informing future conservation decision making processes; (4) encourage greater international collaboration and interaction between countries, as Andean Condors do not recognize borders and

require conservation across various jurisdictions; (5) promote mixed conservation strategies that recognize the role that local communities and private landowners will play in overall Andean conservation across the entire distribution area, and the need to increase environmental education and outreach; (6) work with the governments of the Andean nations to address the most pressing threats to Andean Condor populations, especially including legislation to prosecute the use of poisons in carcasses, and eliminate the risks of lead poisoning.

SUPPLEMENTAL MATERIAL (available online): Spreadsheet S1: Localidades, Amenazas y Unidades Prioritarias para la Conservación del Cóndor Andino.

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