

CAT

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Developing transboundary monitoring of the jaguar in southern South America

During 12–14 March 2018, researchers from Argentina, Bolivia, Brazil, and Paraguay met in Asuncion, Paraguay for the workshop *Developing a transboundary monitoring framework for the jaguar (Panthera onca) in the Southern Cone* towards determining transboundary research needs for jaguar in these four countries. We defined a focal area of interest, which includes 15 Jaguar Conservation Units JCU and seven ecoregions. For this focal area we defined research needs to determine population status and viability, connectivity, and genetic diversity among units, as well as connectivity with the continental core populations in the Amazon. We prioritized conducting research outside of protected areas, particularly in areas dominated by row crops and grazing. Furthermore, we identified a need for increased research on the movement of individuals and genes through the landscape to be incorporated into the assessment of population connectivity. Also, the intentional killing of jaguars needs to be better quantified, including research on the human dimensions of killing, as mortality is high in many areas and limits jaguar occurrence despite the availability of suitable habitat.

Large carnivore conservation strategies require a large-scale, transboundary, perspective due to large spatial requirements (Weber & Rabinowitz 1996, Trouwborst 2015, Gervasi et al. 2019). Such a perspective has been identified as a main component for the range-wide conservation of the jaguar *Panthera onca* (UNDP 2018, Jaguar 2030 Roadmap for the Americas) in response to its widespread decline and local extinction from about 50% of its historical range and by 80% of its range outside of Amazonia (de la Torre et al. 2017). The contraction in the distribution of the jaguar is primarily driven by habitat loss and hunting, stemming from persecution due to real or perceived threats to livestock or people or from opportunistic or culturally driven hunting, which may act synergistically to negatively affect jaguars (Quigley et al. 2017). Additionally, habitat loss and degradation and uncontrolled hunting reduce prey availability, which can increase jaguar depredation of livestock and consequently lead to increased persecution of jaguar (Quigley et al. 2017). The effects of habitat loss and uncontrolled hunting have been most acute at the austral portion of the jaguar's distribution, where the

species has been extirpated from Uruguay, and remains in increasingly restricted populations in Argentina, Paraguay and southern Bolivia and Brazil (de la Torre et al. 2017). These four countries share borders and jaguar populations, and consequently need transboundary cooperation by researchers, stakeholders, and decision makers to maximise the value of applied science and conservation actions for the jaguar.

Recognising the urgent need for transboundary cooperation for jaguar research and conservation, researchers working in borderland areas of Argentina, Bolivia, Brazil and Paraguay met in 12–14 March 2018 in Asunción, Paraguay, in a workshop to define transboundary research needs and objectives for the long-term conservation of the jaguar at the southern limit of its distribution. Through the sharing of information and experiences among researchers, we assessed the current state of knowledge of jaguar populations' ecological and genetic status in border regions of the four countries, identified and prioritised research needs, and established a framework to incorporate information into the decision-making process.

The transboundary region supports seven ecoregions (Atlantic Forest, Cerrado, Chiquitano Forest, Dry Chaco, Humid Chaco, Pantanal and Argentine and Bolivian Andean forest; Olson et al. 2001) and contains six Jaguar Conservation Units (JCU; Sanderson et al. 2002, Zeller 2007), four of which span across more than one country (Fig. 1). We focused our evaluation on the seven transboundary ecoregions, acknowledging the importance of transboundary areas for maintaining functional and genetic connectivity among southern jaguar populations (Paviolo et al. 2006, DeAngelo et al. 2013, Thompson & Velilla 2017). However, we also recognised the importance of maintaining connectivity of all southern jaguar populations with larger core populations in the Amazon. Consequently, we defined a broader focal area surrounding the transboundary area that includes all or part of 15 JCUs (Fig. 1).

Focal-region specific research priorities

Given the importance of anthropogenic effects in determining jaguar occurrence we recognised, apart from ecoregional priorities, an overarching need across the focal area to place greater emphasis on conducting research outside of protected areas, particularly in crop and grazing lands as the number and size of protected areas in the focal area is li-

mited and likely insufficient to maintain functioning jaguar populations, which highlights the critical role of private lands for the long-term conservation of the jaguar in the region. Furthermore, the fragmentation of populations and uncertainty about the movement of individuals and genes through the landscape points to an increased need for research into the genetic structure and diversity, including the functional connectivity, among jaguar populations throughout the focal region. Equally important, we recognised the role of the intentional killing of jaguar in reducing jaguar numbers and distribution throughout the focal region and the need for increased research into the human dimensions of jaguar killing towards developing actions to reduce jaguar mortalities.

Ecoregion-specific research priorities

Atlantic Forest

The Atlantic forest is highly fragmented and its jaguar populations confined to large, isolated forest remnants in Argentina, Brazil and Paraguay. Of the original 1.7 million km² of forest, only ~2.8% of the ecoregion is occupied by jaguar and only about 7% of remaining habitat (<100,000 km²) is considered adequate for the species (Paviolo et al. 2016). Although most populations are isolated and connectivity is low, with individuals primarily dependent upon protected areas (Paviolo et al. 2016, McBride & Thompson 2019), there is increasing evidence of the use of smaller forest remnants by jaguars (Casanova & Bernardo 2017, Brocardo 2018, Casanova et al. 2018). This illustrates an ability of jaguars to move through the highly anthropic matrix surrounding forest remnants. However, as multiple studies in the region have illustrated drift-induced loss of genetic diversity within many of these populations (Haag et al. 2010, Roques et al. 2016, Srbek-Araujo et al. 2018); we recognised a need to quantifying the occurrence of jaguar in smaller remnants of Atlantic Forest and the movements of individuals and genes through the landscape.

Cerrado

Although within the immediate transboundary area the Cerrado only occupies a small area along the Brazil-Paraguay border, we recognised the potential but neglected importance of the Cerrado in maintaining connectivity among austral jaguar populations and with Amazonian populations. Jaguar numbers and distribution in the Cerrado have been greatly reduced, principally stemming from habitat

conversion for row crop agriculture and cattle pasture, so that about 30% of the ecoregion, mostly at its eastern extent, is now suitable for jaguar (Klink & Machado 2012, Moraes et al. 2012, Portugal et al. 2019). Furthermore, more locally, mining and associated infrastructure negatively affect jaguar habitat (Moraes et al. 2012).

Despite the extensive anthropogenic impacts on the Cerrado it supports multiple isolated populations of jaguar (Sollmann et al. 2011, Moraes et al. 2012, Silveira et al. 2014, Portugal et al. 2019). There is ample evidence of jaguar movements throughout the Cerrado, including through highly human-altered landscapes. The origin of individuals observed in habitat remnants in many areas of the Cerrado, however, is often unclear, which, as with the Atlantic Forest, points to a conspicuous need to determine the occurrence of jaguar in habitat remnants and their movements and functional connectivity throughout the system.

The Gran Chaco

The Gran Chaco, divided into the Dry and Humid Chaco is a global deforestation hot spot (Kuemmerle et al. 2017) where historic and ongoing deforestation and killing of jaguar drives the contraction of the distribution of jaguar within the system (Romero-Muñoz et al. 2018). The jaguar has been nearly extirpated in the Argentine Chaco (Quiroga et al. 2014), is relatively rare in the Bolivian Chaco south of the Kaa-lya National Park (Maffei et al. 2016, Thompson et al. 2020), and is extirpated in most of the Humid Chaco except for a population at the northern limit of the system in Paraguay and isolated individuals in the remainder of the system in Paraguay and in the province of Formosa in Argentina (McBride & Thompson 2018, authors pers. obs.).

We recognised the importance of the triple border area of Argentina, Bolivia and Paraguay in maintaining a contiguous population in the Dry Chaco across the three countries and that Paraguay and the Kaa-lya National Park in Bolivia serve as an important source for individuals in the Argentine and southern Bolivian Chaco (Romero-Muñoz et al. 2018). However, information on the region-wide occurrence of jaguar in the triple border region is incomplete and needs to be addressed. Furthermore, at the regional level, there is a need for a more holistic view of jaguars in Dry Chaco, Humid Chaco, and southern Pantanal as a single population in this region. This includes research on the extent, magnitude, human dimensions, and drivers of anthropo-

genic mortalities in reducing the numbers and distribution of jaguar in the region, illustrated by extensive areas of suitable habitat in the Gran Chaco that are void of jaguars (Romero-Muñoz et al. 2018).

Additionally, the conservation implications of the bi-oceanic highway (dubbed South America's new Panama Canal; Parks 2019) connecting Brazil with Chile by crossing Paraguay and Argentina, need to be considered (<https://www.mopc.gov.py/mopcweb/index.php/corredor-bioceanico/ubicacion-bioceanica>). This project, and associated development, will bisect the Dry Chaco and isolate jaguars in the Paraguayan Humid Chaco and southern Pantanal from the Pantanal to the north and the Dry Chaco to the west, while increasing the human footprint in the region.

Pantanal

Although the large majority of the Pantanal remains intact, it is almost completely utilised for livestock production, although row crop agriculture and mining are additional land uses (Tomas et al. 2019), while a relatively small amount of the Pantanal is in formally protected areas. For example, in the Brazilian Pantanal, which comprises 65% of the Pantanal, only 7% of the area is under some form of protection (Tomas et al. 2019). Although for our entire focal area we recognised the importance for research to include unprotected areas, the need for research outside of protected areas in the Pantanal is particularly acute as most data collection is not occurring within unprotected rangelands that are representative of the majority of the jaguar distribution within the Pantanal.

As previously mentioned, we believe that there is a need to view jaguars in the Gran Chaco and the southern Pantanal as a single population and consequently we viewed the delineation and separation of the Gran Chaco and Pantanal JCU as a hindrance to more holistic, integrated research and conservation planning in the region. Since at their closest point these JCU are separated by only 15 km, do not completely include all proximal protected areas or the west bank of the Rio Paraguay (eastern Dry Chaco, Paraguayan Pantanal and northern Humid Chaco), which supports some of the best jaguar habitat in Paraguay, we concluded that a combination and revised delineation of the Gran Chaco and Pantanal JCU into a single JCU would serve to better focus jaguar research and conservation in the region.

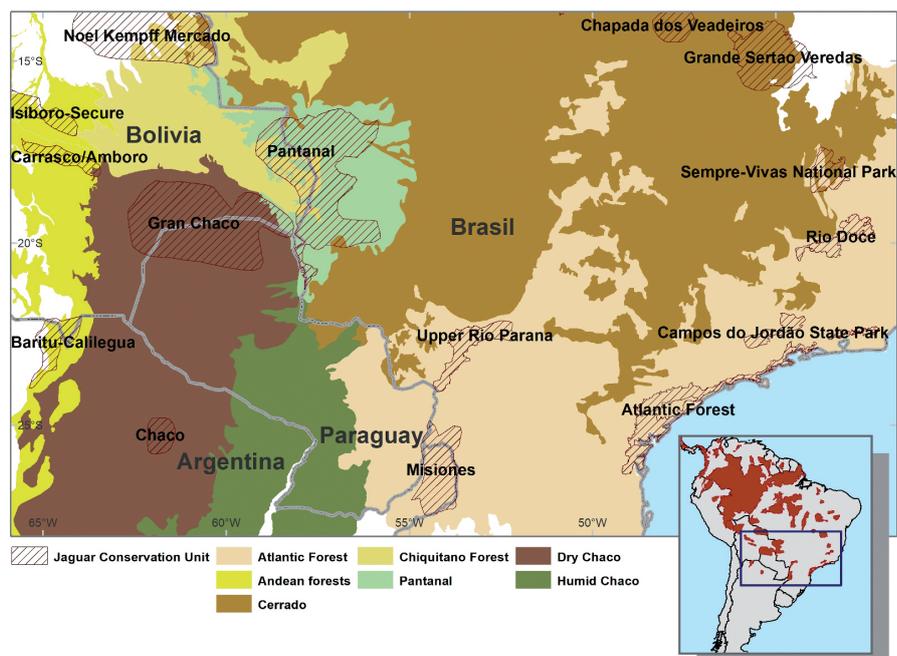


Fig. 1. Focal area of interest that includes the Argentina-Bolivia-Brazil-Paraguay transboundary region showing ecoregion distributions (Olson et al. 2001) and Jaguar Conservation Units (Zeller 2007) with their names. Inset shows the location of the focal area within South America.

Chiquitania

Since the Chiquitano forest in eastern Bolivia is one of the more important pathways to maintain connectivity of the southernmost jaguar populations with the Amazon (Rabinowitz & Zeller 2010, Thompson & Velilla 2017), the large-scale agricultural development of the region (Killeen et al. 2008), promoted by national level policies (Romero-Muñoz et al. 2019), and associated habitat loss over the last several decades have driven declines in jaguar population and connectivity (Maffei et al. 2016, Thompson & Velilla 2017). The expanding infrastructure associated with agricultural expansion is an additional concern, particularly the highway connecting Santa Cruz de la Sierra with Puerto Suárez in Bolivia and Corumbá in Brazil, as it is promoting further deforestation and increasingly obstructing movement among the Gran Chaco, Pantanal and Chiquitano.

Although jaguar occurrence and density have been estimated at sites in the Chiquitania (Maffei et al. 2016, Polisar et al. 2017), these estimates are relatively dated given the continuing expansion of the agricultural frontier and indicate a need for a re-evaluation of jaguar distribution and the impacts of increasing human pressures on jaguar density in the Chiquitania. Moreover, based upon the role of the Chiquitania in maintaining connectivity in the focal area,

there is a need for understanding jaguar movements and space use as well as gene flow within the context of the ongoing land use changes and associated development of infrastructure in the region.

Northern Argentine and Southern Bolivian Andean forest

Within the focal area the forests on the eastern slope of the Andes within and among JCU are comprised of the Southern Andean and Bolivian Yungas, Bolivian montane dry forest, and southwest Amazon moist forest (Olson et al. 2001). This region is under multiple threats, including road development, gas exploration, and habitat loss and degradation associated with relatively high human population densities in some areas (Martínez Martí 2015).

The amount of research and information on jaguar populations in the Yungas, both historically and ongoing, in the Argentina-Bolivia border region is more extensive for Argentina than in Bolivia. However, available information indicate that jaguar have higher occurrence in Argentina than in Bolivia (Cuyckens et al. 2014, Maffei et al. 2016, Thompson et al. 2020). More northward, an evaluation of the status of jaguar in and around the Carrasco/Amboro and Isiboro-Secure JCU is needed, as well as an assessment of connectivity among JCU in the region and with the Gran Chaco.

Looking to the future

We readily admit that the aforementioned research prioritisation may not be all inclusive, but collectively we defined these needs as the most pressing at the scale of our revision. The principal importance of defining common objectives across the focal area and within ecoregions is to provide a research framework to strengthen collaboration across borders. Towards facilitating collaboration and data sharing, based upon our process of organising information for our ecoregional assessments, we developed a conceptual framework to prioritise research needs and to provide a workflow for deriving a quantitative assessment and categorisation of the jaguar population at the regional and ecoregion level (Fig. 2). Our conceptual framework considers estimates of distribution, population size, connectivity and genetic structure, based upon data on presence-only, detection/no detection, movement, spatial capture recapture, population genetics, and biotic and abiotic landscape factors. Moreover, the framework considers prey availability and socio-economic-political factors such as jaguar-human conflict, law enforcement, and public perceptions, among others, to holistically assess the region-wide conservation status of jaguars in the focal

area and the species' long-term potential for survival (Fig. 2). Public participation in the monitoring of jaguar in the Upper Paraná Atlantic Forest and the Argentine Dry Chaco has been successful in generating data and as a basis for environmental education programmes (DeAngelo et al. 2011, Cirignoli 2017) and can serve as a model for future initiatives in our focal area. To facilitate public participation, we believe that the development of a cell phone application to register detections of jaguars and relevant information (georeferenced photographs of individuals or footprints, livestock depredations, etc.) would greatly facilitate recording detections by researchers and the public, and would allow for the development of an integrated cross-border database of jaguar occurrence. The focus of our workshop was to address research needs on the ecology of jaguar within the context of cross-border collaboration, however, given the dominant effect that anthropogenic factors have on jaguar ecology, there are obvious additional research needs on human dimensions and the effectiveness of law enforcement, policy, and conflict mitigation on jaguar ecology throughout the focal area. Although these topics were outside the scope of our exercise, we recognise a need

for multi-national research in these areas to be applied in conjunction with ecological research for region-wide conservation actions in the trans-boundary region.

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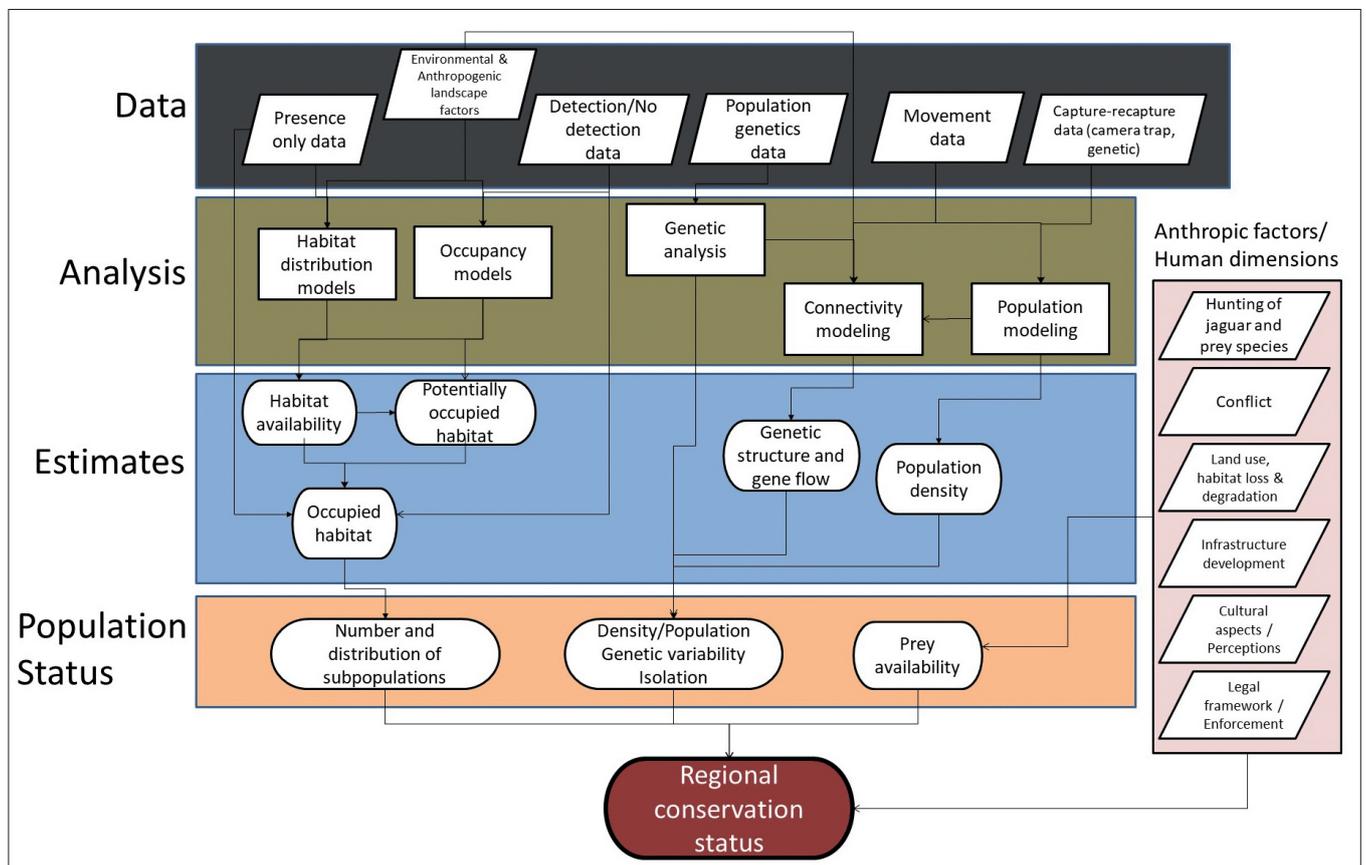


Fig. 2. Conceptual framework to evaluate the regional conservation status of jaguar by integrating environmental and monitoring data and their analyses to derive the status of jaguar populations in relation to regional socio-political-economic factors.

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