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Conservation units, priority areas and dispersal corridors for jaguars in Brazil

The National Action Plan Workshop for jaguars *Panthera onca* in Brazil, 2009, brought together jaguar experts from all over the country to strategize a survival plan for the jaguar in Brazil. The experts developed a consensus on significant jaguar populations, priority areas for jaguar conservation and parameters important for building a corridor model to identify connections between source populations. Twenty jaguar populations, called Jaguar Conservation Units (JCUs), were identified across five different biomes in the country. Detailed data collected on jaguar densities, important prey species, key threats, habitat quality and knowledge gaps for each JCU resulted in a comprehensive database that will be a central repository of jaguar information for Brazil. In addition, twenty four priority areas deemed important for long-term survival of the jaguar and associated conservation actions were identified. Although the framework used in this exercise is an adaptation of the methodology by Sanderson et al. (2002) and was established for jaguars, it can be used as a model to develop similar schemes for geographic priority setting, especially for single-species based conservation planning at the country level.

The jaguar is the largest feline in the Americas and historically ranged from the southwestern United States to southern Argentina (Guggisberg 1975). At the beginning of the 21st century, jaguars occupied less than 50% of their historic range (Sanderson et al. 2002). An estimated 50% of this remaining habitat lies in Brazil making it one of the most important countries for long-term survival of this keystone species. Brazil's role in the range-wide conservation of the jaguar is also crucial because it contains more than half of the Amazon basin, which is the single largest contiguous block of remaining jaguar habitat (Sanderson et al. 2002).

In 1999, the Wildlife Conservation Society (WCS) and the National Autonomous University of Mexico organized a range-wide priority setting and planning exercise for the jaguar by bringing together experts from 18 range countries. These jaguar experts unanimously identified currently known jaguar range and areas with significant jaguar populations, suitable habitat, and a stable and diverse prey base, called Jaguar Conservation Units (JCUs) (Sanderson et al. 2002; Zeller 2007). Ninety JCUs (updated by Zeller 2007), representing 1.9 million km² or 10% of the historic jaguar range, were identified as being important to the long-term survival of jaguars. Twenty-six jaguar populations in Brazil were included in the JCU framework. Although range-wide planning exercises are instrumental in bringing attention to threats

and conservation priorities of a wide ranging species like the jaguar, their extensive geographic scope and coarse filter approach does not allow for attention to country or region-specific conservation needs for the species. National Action Plan Workshops, such as the one held in Brazil in November 2009 (the ‚Workshop‘), provide perfect opportunities for performing a finer scale assessment of threats and conservation challenges unique to the country. Subsequently, this allows for the development of appropriate action plans to address those challenges. The workshop served as an important venue to identify key populations or JCUs in Brazil, update the existing range-wide JCU database with data from recent studies, collect vital information on jaguar densities and key threats, and develop a consensus between Brazilian experts to create a prioritization scheme best suited to jaguar conservation in Brazil.

Rapid expansion of agriculture and cattle ranching in Brazil is dividing jaguar habitat into progressively smaller fractions. This human induced habitat fragmentation leads to isolated populations which in turn reduces exchange of genetic material by eliminating dispersal routes and can eventually contribute to extinction risk for a population (Frankham 2005). Therefore, corridors are crucial for maintaining genetic viability in populations, rescuing small inbred populations and ameliorating harmful effects of habitat fragmentation (Hilty et al. 2006). Recent genetic

research (Eizirik et al. 2001; Ruiz-Garcia et al. 2006) has shown little evidence of significant geographical partitions among jaguars and has highlighted the fact that the jaguar has maintained relatively high levels of gene flow throughout its range. Given this, dispersal corridors have been included in the National Action Plan as a way of protecting jaguars outside the protected area network. The workshop initiated the process of identifying movement corridors between the JCUs. Once the corridors are identified, conservation actions can begin to secure these connections for the future.

Another important aim of the workshop was to develop a strategy to prioritize conservation actions and interventions for jaguar habitats and populations. The jaguar is found in five distinct biomes in Brazil: Amazonia (the Amazon rainforest), Caatinga (semi-arid scrubland), Cerrado (savannah), Pantanal (the Pantanal floodplain) and Mata Atlantica (the Atlantic Coastal forest). Jaguar ecology differs widely between these biomes, as does the habitat and prey base (Astete et al. 2008). Therefore, it is important to consider these differences while developing a prioritization scheme that would be best suited to jaguar ecology and conservation challenges of each biome. This biome-based approach was also adopted for developing corridors and identifying JCUs.

This paper presents the results of the JCU identification and prioritization scheme that emerged from the workshop. The JCU methodology used here is in conformance with conservation protocols that have been implemented by Panthera and WCS throughout jaguar range with adaptations to account for ecological and socio-political conditions in Brazil. This standardization of the basic scientific protocols across the range enables easy comparison of strategies and extrapolation of successful actions to similar areas. Although the results focus on the conservation action plan of jaguars in Brazil, the methodology (pioneered by Sanderson et al. 2002) used and the lessons learned present a conservation model that could be used for other country-specific workshops for wide-ranging species.

Methods

Twenty three jaguar experts from a total of thirty five workshop participants contributed to this exercise. The experts were divided into five groups based on their biome of expertise. Each biome group convened for a discussion session where they received a detailed ex-
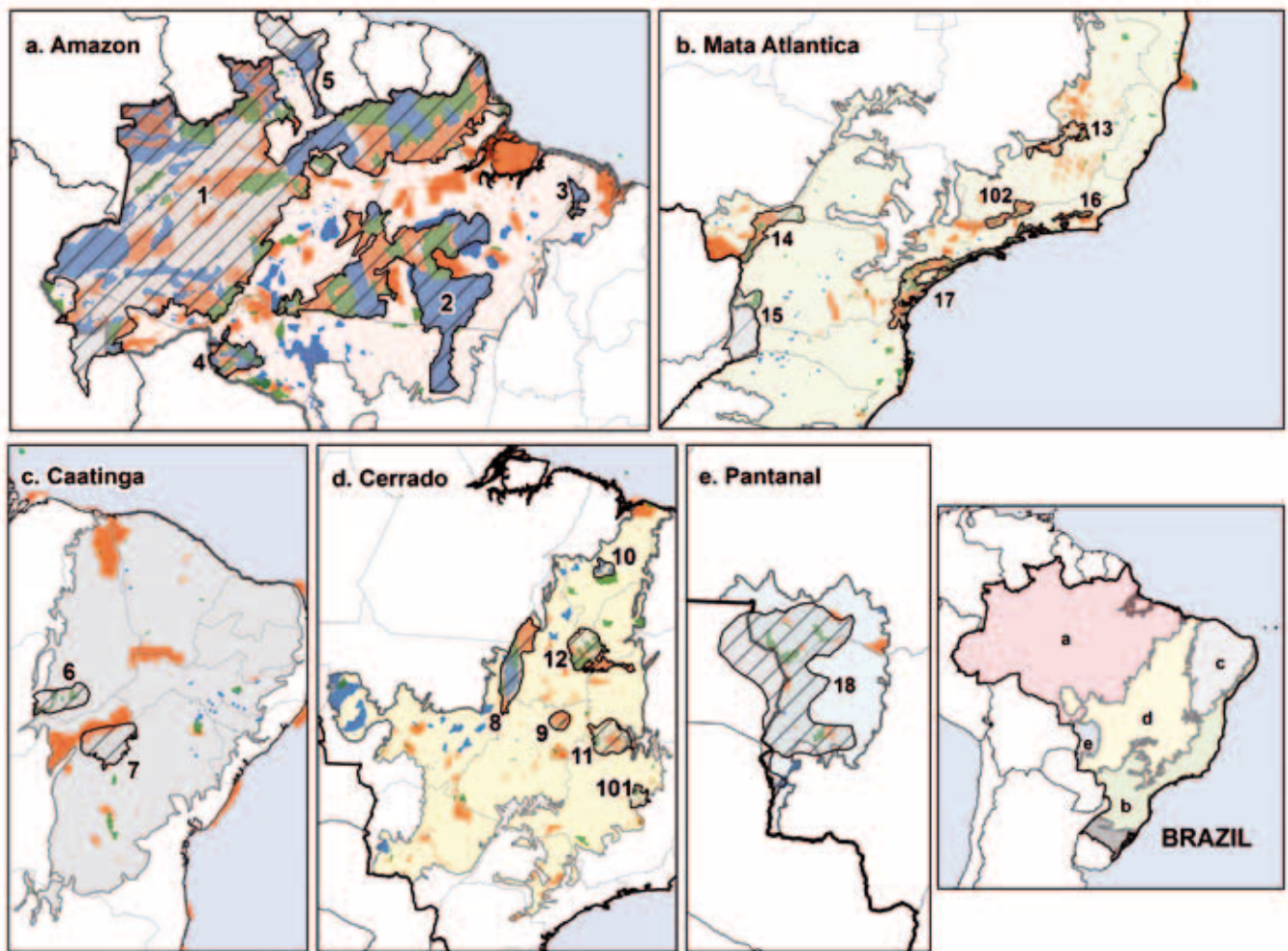
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Fig. 1. Jaguar Conservation Units (black hatched polygons) in five biomes in Brazil. JCU IDs correspond to the IDs in SOM Table 1. Red: Restrictive-use forest reserves including state forests, national forests, extractive reserves, natural monuments, municipal natural parks, wildlife refuges, natural heritage reserves, sustainable development reserves and environmental protection areas. Green: national parks, state parks, biological reserves and ecological stations. Blue: Indigenous reserves.

planation of the JCU methodology, maps of their biome and the existing JCU database for Brazil (Zeller 2007). The maps showed the existing JCUs and basic reference information including lines of latitude and longitude, state boundaries, major rivers and towns, elevation, protected areas and forest cover at a 1:2,000,000 – 1:6,000,000 scale. Data used in these maps were acquired from IBAMA (Brazilian government agency for the environment), MMA (Ministry for the Environment) and IBGE (Brazilian institute of Geosciences and Statistics).

The existing JCU framework (Sanderson et al. 2002) including what qualifies as a JCU in a particular biome and the existing JCU database for Brazil were examined systematically within the biome groups to resolve disagreements. When a consensus was reached, existing JCUs were modified and new JCUs were delineated on the maps using protected area boundaries, roads and forest cover as guidelines. The JCU information base was

subsequently updated with new information on JCU type, population size, key prey species (in order of importance by biomass) and effectiveness of land tenure in the area.

Additional information on threats, not a part of the 1999 and 2007 range wide exercises, was also solicited for the JCUs whenever available. The experts were also asked to report approximate jaguar densities from their areas of study and the method used for density estimation. Hunting of jaguars and prey was reported in the form of five subjective categories: no hunting, low, moderate, high and subsistence only. Detailed information on resource extraction including mining and agricultural operations was also collected. This standardized format was adopted across the biomes.

Jaguar Conservation Units

At the range-wide exercise in 1999 Jaguar Conservation Units were defined either as:

Type I: areas with a stable prey community,

currently known or believed to contain a population of resident jaguars large enough (at least 50 breeding individuals) to be potentially self-sustaining over the next 100 years, or

Type II: areas containing fewer jaguars but with adequate habitat and stable diverse prey base, such that jaguar populations in the areas could increase if threats were alleviated (Sanderson et al. 2002).

JCUs were not restricted to or required to contain protected areas. During the group discussions at the workshop, another type of JCU was proposed:

Type III: An area can be classified as a type III JCU, also called Potential or Research JCU, if unconfirmed records suggest that it has jaguars, however, no density/population estimates are available for jaguars and prey due to lack of research. A type III JCU should have a strategic location important for connectivity within or between the biomes and there should be anecdotal evidence of good prey density and diversity. The importance
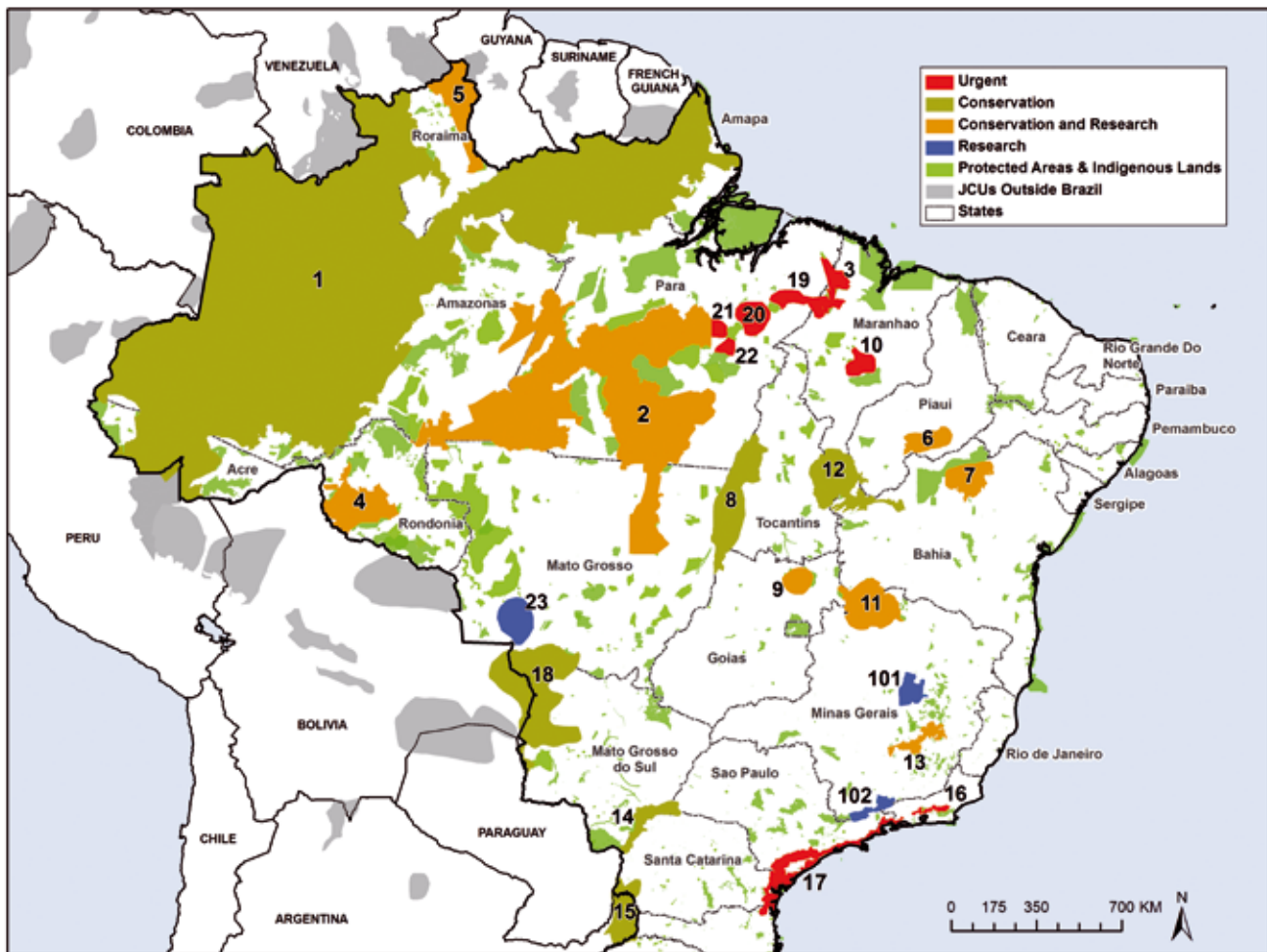
Fig. 2. Priority areas in Brazil and their action categories.

of introducing a 'Potential JCU' category is to draw attention to the need for research to ascertain their status as a JCU. The new JCU category created for Brazil does not necessitate inclusion in the 'Jaguars in the New Millennium" range-wide data set.

Different biomes in Brazil represent regional differences in species composition, geographical parameters, jaguar population status, socio-political factors, information availability and area under legal protection. Therefore, the experts agreed that wherever necessary, the JCU criteria should be altered appropriately depending upon the status of jaguars in a biome. The overall JCU categorization (Type I, II, III) was kept consistent across the biomes however; the assignment of JCU categories to jaguar populations was governed by biome-specific factors. For example, the jaguar is on the verge of extinction in Mata Atlantica due to excessive hunting and habitat loss (Crashaw 1995; Leite & Galvao 2002) whereas there are still extensive areas of intact rainforests in the Amazon that support some of the highest jaguar densities (Ramalho 2006). Consequently, for

Mata Atlantica, JCUs were extended to include any legally protected area with confirmed jaguar presence deemed important for maintaining connectivity within the biome. This definition would not apply to Cerrado or Pantanal where jaguars are doing much better.

The Amazon is unique because over 50% of the biome is legally protected (Sollmann et al. 2008) and majority of the forests are well connected representing a large continuous jaguar population. Therefore, experts contended that the Amazon should not be broken up into discrete populations unless there are significant physical barriers. To aid the identification of JCUs in Amazonia, a map of current deforestation (PRODES, 2008) and studies simulating deforestation rates under different futuristic scenarios (Soares-Filho et al. 2006) were considered. Final JCUs were delineated based on a combination of large and healthy jaguar populations, presence of protected areas and areas that are predicted to remain intact for more than 50 years under various simulated deforestation scenarios.

Priority areas

All the JCUs are important for jaguar conservation. However, in addition to the JCUs, the experts also identified other areas that may not have a significant resident jaguar population but were thought to be crucial for long-term jaguar conservation. For example, parts of eastern Amazon have been severely fragmented by the advancing deforestation belt. These areas, most of which have high rate of endemism, can no longer support resident populations of jaguars but are crucial stepping-stones for connectivity to western Amazon. JCUs and these other 'important areas' are collectively called 'Priority Areas' for jaguars. The experts developed a framework to assign appropriate broad scale actions to the priority areas that seek to address their most pressing conservation need. Reaching consensus, the experts assigned priority areas to one of the following four action categories:

1. Urgent Action: If substantial protection is not given, jaguars in these areas are likely to go extinct in the next 5 years. Ample ecological research has highlighted key threats and indicated the need to develop stronger ma-

nagement and conservation policies. These areas should either be legally demarcated as "protected areas (national park, state park)" or upgraded to a "higher level of protection". Simultaneously, all exploitation should be stopped and security should be tightened. To be included in the 'urgent action' category, a priority area should meet at least two of the following criteria: 1) represent an endangered population in a biome, 2) be crucial for connectivity in the region (within or between the biomes), 3) have lost a sizeable percentage of forest, or 4) not only be important for jaguars but a biodiversity hotspot for other species as well.

2. Conservation Investment: ongoing research has documented population status of jaguars and their prey and, the key threats. The focus should be to develop strategies to mitigate the threats.

3. Conservation and Research Investment: preliminary research has identified them as important areas for jaguars but more research is needed to determine the population status of jaguar and prey and identify main threats. These areas should receive immediate funding for more research aimed at guiding conservation actions.

4. Research Investment – researchers claim that these areas are important for jaguars but even basic socio-ecological information is unavailable. Research investment is needed to ascertain jaguar population, threats, and subsequent importance for inclusion in the prioritization framework. Most type III JCUs fall under this category.

Dispersal Corridors

Experts in biome-based groups identified landscape and ecological factors that are thought to affect jaguar dispersal behavior in their respective biomes. Some of the landscape parameters selected were: land cover type, human population density, distance from human settlements (cities, towns and villages), forest cover, infrastructural projects like dams and mines, waterways, protected areas, roads (paved/unpaved) and livestock density. Some biome specific layers such as fire propensity for Cerrado and Pantanal, ranch boundaries for the Pantanal and indigenous lands for the Amazon were also included in the movement model. We are in the process of collecting up to date GIS data on afore mentioned layers from Brazilian governmental agencies. The next step is to create a connectivity model to identify functional corridors between the JCUs.

Results

Based on current jaguar population centers and size, prey status and habitat quality, twenty JCUs (Fig. 1) were identified throughout Brazil covering 2.46 million km^2 or 28.89% of the country. These areas represent core jaguar populations that form the baseline for jaguar conservation in Brazil. Nine, nine and two JCUs were classified as type I, II and III respectively. Type III JCUs are located in Cerrado and Mata Atlantica each. The JCUs vary in area from 1,652 km^2 to 1.69 million km^2. The smallest JCU is in the Atlantic Coastal forests near the major city of Rio de Janiero. JCUs cover a staggering 51% of Amazonia as opposed to a mere 4% of Caatinga. Mata Atlantica and Cerrado have the highest number of JCUs while the Pantanal has only one.

Nearly 40% of the net JCU area falls within the protected area system in Brazil. Protected areas are divided into two categories, strictly protected and restrictive use, based on the level of protection. If indigenous lands are included, then nearly 70% (Supporting Online Material SOM Table 2) of the net JCU area is under some level of legal protection. The JCU area under protection is highest in Amazonia and lowest in the Pantanal.

The experts unanimously delineated the biggest JCU, at 1.69 million km^2, (JCU # 1, SOM Table 1) in jaguar range. JCU # 1 covers nearly 40% of the Amazon rainforest in Brazil and 20% of continental landmass of Brazil. 40% of this JCU is strictly protected through a network of national and state parks whereas nearly 24% is demarcated as 'restrictive use' forests and 32% as indigenous lands. This JCU represents the single largest contiguous population of jaguar in the entire range crossing over into the Amazon rainforest in Peru, Venezuela and Colombia.

The experts were also asked to report on the six most important prey species, in terms of biomass consumed, for jaguars within a JCU (SOM Table 1). Prey preference varied greatly among the JCUs but overall, the two tayassu species were the most important prey items. Livestock constitutes an important jaguar prey in the Pantanal.

Highest reported jaguar density was in the Amazon where some areas harbor around 10 individuals per 100 km^2. JCUs in Cerrado and Caatinga have low densities due to a lower carrying capacity of these semi-arid habitats. JCUs in Mata Altantica also have extremely low jaguar densities largely due to anthropogenic activities. Most JCUs

are affected by some degree of hunting of jaguar and prey, however, highest hunting pressure was reported for the Pantanal and some JCUs in Mata Atlantica. The most common threat to the JCUs is deforestation for agriculture followed by livestock-wildlife conflict.

All the JCUs and four additional areas were classified into four priority action categories (Fig. 2). Eight areas came under the urgent category whereas three areas were recommended for research and exploration category. Four non-JCU areas were included in the priority areas system because they were deemed important as stepping-stones for jaguars and other endemic species.

Discussion

The framework used in this exercise is an adaptation of Jaguars in the New Millennium (by Sanderson et al. 2002) from a general range-wide approach to a more detailed country level approach that incorporates social, political and ecological factors unique to the country. Although this methodology was originally established for jaguars and is derived from a wide array of expert driven, geographic priority setting exercises undertaken over the years, it can be used as a model to develop similar schemes for geographic priority setting, especially for single-species based conservation planning at the country level (Sanderson et al. 2002). An important achievement of this workshop is the creation of a comprehensive, peer-reviewed database of key jaguar populations, prey base and associated threats that should form the basis of conservation of this flagship species in Brazil. Expert derived datasets have inherent limitations such as inaccuracies due to personal opinions and different interpretations of the survey by the experts. Some experts felt comfortable reporting only on their small study area but others extrapolated the status of jaguars over an entire JCU. Additionally, the more intimate a researcher is with a place, the more they see the presence of threats and vice versa. This dataset is robust because it is a result of experts reconciling these differences of interpretation and reaching a consensus on the JCU polygons and associated attribute data.

Vital information, such as jaguar densities, focal prey species and detailed regional threats, was collected for each JCU during the workshop in a standardized format. This comprehensive repository of information on specific jaguar populations should be the key

dataset for informing policy at national level. JCU polygons carefully delineated using protected areas and land cover/land use types as a guideline resulted in the most up to date spatial information on jaguar populations in Brazil. This methodology recognizes the significance of corridors in an increasingly human dominated landscape. The next step is to build an expert-driven connectivity model to identify dispersal corridors between the source populations so that they can be implemented through the national action plan.

A significant development in the workshop was a joint expert agreement on the boundaries of JCU # 1. Modeling studies (Soares-Filho et al. 2006) simulating deforestation and development in the Amazon under various futuristic scenarios were incorporated in delineating a population that would remain preserved for over 50 years even under worst-case conditions. Isolation, lack of infrastructure and 71% coverage by a network of protected and indigenous reserves topped with active management will ensure a safe future for this biggest and best jaguar habitat. JCU # 1 and several other JCUs are connected to populations in other countries suggesting that jaguar conservation is not a national or a regional issue. Jaguars are not confined by political borders therefore; the success of conservation in these transboundary JCUs would entail cooperation of the range countries.

All the JCUs are important for jaguars, however they vary in level of threat to jaguars, size, habitat quality and probability of long term-term survival. The prioritization scheme developed here seeks to highlight the most urgent need for the JCUs and other key jaguar habitats so that appropriate resources can be channeled. Specific activities and detailed action plan will be created for each priority area using the National Action Plan manual produced at the workshop.

Illegal hunting of jaguars and prey and loss of habitat to agriculture are the two major threats that need immediate attention, despite laws prohibiting hunting (IBAMA 2000). Mata Atlantica has suffered the highest incidence of habitat loss in Brazil; 71% of its land is under anthropogenic use and the remaining forests are almost entirely confined to protected areas (MMA 2007). This underscores the importance of effective management of protected areas for the success of the action plan.

The current state of the jaguar shows that healthy populations exist throughout Brazil, and that there are also populations that are in decline due to increasing threats that come from human population growth. Results from other analyses, such as ecological niche modeling and population viability (see Ferraz et al. 2012, this issue, and Desbiez et al. 2012, this issue) should be combined with the one presented here to inform the most scientifically robust conservation decisions.

References

Astete S., Sollmann R., & Silveira L. 2008. Comparative ecology of Jaguars in Brazil. Cat News Special Issue No 4, 9-14.

Crawshaw Jr. P. G. 1995. Compartive ecology of ocelot (*Felis pardalis*) and jaguar (*Panthera onca*) in a protected subtropical forest in Brazil and Argentina. University of Florida, Gainesville.

Eizirik E., Kim J., Menotti-Raymond M., Crawshaw P. G., O'Brien S. J. & Johnson W. E. 2001. Phylogeography, population history and conservation genetics of jaguars (*Panthera onca*, Mammalia, Felidae). Molecular Ecology 10, 65-79.

Frankham R. 2005. Genetics and extinction. Biological Conservation 126, 131-140.

Guggisberg C. A. W. 1975. Cats of the World. Taplinger Publications Co., New York.

Hilty J. A., Lidicker Jr. W. Z. & Merenlender A. M. 2006. Corridor ecology: the science and practice of linking landscapes for biodiversity conservation. Island Press, Washington D.C.

IBAMA. 2000. Lei do Sistema Nacional de Unidades de Conservação No. 9.985 do 18 de julho de 2000. IBAMA, Ministério do Meio Ambiente, Brasilia. http://www.mma.gov.br/port/sbf/dap/doc/snuc.pdf ; July 2008.

Leite M. R. P. & Galvão F. 2002. El jaguar, el puma y el hombre en tres áreas protegidas del Bosque Atlántico costero de Parana, Brasil. In El jaguar en el nuevo milenio. Medellin et al. (Eds). Ediciones Científicas Universitárias, Universidad Nacional Autónoma de Mexico/ Wildlife Conservation Society, New York, USA, pp. 237-250.

MMA 2007. Levantamento da Cobertura Vegetal Nativa do Bioma Mata Atlântica Relatório Final. Edital PROBIO 03/2004 http://mapas.mma.gov.br/maps/aplic/probio/datadownload.htm; June 2008.

PRODES. 2008. http://www.obt.inpe.br/prodes/.

Ramalho E. 2006. Uso de habitat e dieta da onça-pintada (*Panthera onca*) em uma área de várzea, Reserva de Desenvolvimento sustentável de Mamirauá, Amazônia Central, Brasil. MSc dissertation. Universidade Federal do Amazonas, Brazil. 60 pp.

Ruiz-Garcia M., Payan E., Murillo A., & Alvarez D. 2006. DNA Microsatellite characterization of the jaguar (*Panthera onca*) in Colombia. Genes Genet. Syst. 81,115-127.

Sanderson E. W., Redford K. H., Chetkiewicz C. B., Medellin R. A., Rabinowitz A. R., Robinson J. G. & Taber A. B. 2002. Planning to Save a Species: the Jaguar as a Model. Conservation Biology 16, 58-71.

Soares-Filho B. S., Nepstad D. C., Curran L. M., Cerqueira G. C., Garcia R. A., Ramos C. A., Voll E., McDonald A., Lefebvre P. & Schlesinger P. 2006. Modeling conservation in the Amazon basin. Supplementary Information. Nature 440, 520-523.

Sollmann R., Munim Torres N. & Silveira L. 2008. Jaguar Conservation in Brazil: The Role of Protected Areas. Cat News Special Issue No 4, 15-20.

Zeller K. A. 2007. Jaguars in the New Millennium Data Set Update: The State of the Jaguar in 2006. Wildlife Conservation Society, Bronx, New York. 77 pp.

Supporting Online Material SOM available at www.catsg.org/catnews

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