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Jaguar in Brazil

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CATnews is the newsletter of the Cat Specialist Group, a component of the Species Survival Commission of The World Conservation Union (IUCN). It is published twice a year, and is available to members and the Friends of the Cat Group.

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Cover Photo: Jaguar in the Pantanal
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A National Action Plan for the jaguar in Brazil

Species-focused conservation action plans supply a blueprint for saving a species or group of species. Through a species focus, a greater level of conservation investment to whole ecosystems is stimulated. The IUCN Species Survival Commission is currently working with its networks to improve species conservation planning techniques. The SSC Species Conservation Planning Sub-Committee has been formed to learn from past experiences and to further develop and test processes that lead to effective, realistic, measurable and implementable conservation plans. The IUCN/SSC Cat Specialist Group and the IUCN/SSC Conservation Breeding Specialist Group have been very active participants in these initiatives. Both groups have many years of experience working together with diverse stakeholders throughout the world to develop conservation planning approaches.

In this Special Issue of Cat news we present the process, tools and some results from the Jaguar National Action Planning Workshop held in Atibaia, State of São Paulo, Brazil, in November 2009. It was organised and funded by CENAP - Centro Nacional de Pesquisa e Conservação de Mamíferos Carnívoros (a governmental agency responsible for all aspects of carnivore research, conservation, and policy-making in Brazil), Pró-Carnívoros (a national non-governmental organization dedicated to carnivore conservation) and Panthera (an international NGO). The Brazilian Network of the Conservation Breeding Specialist Group together with the Cat Specialist Group designed and facilitated the workshop.

An action plan is prepared through inclusive, participatory processes. A diversity of stakeholders worked tirelessly together in both small working groups and plenary sessions through a series of carefully planned steps to prepare the national action plan. This process and some results are presented in the first article of this issue.

Globally, jaguars are listed as "Near Threatened" (IUCN 2011). In Brazil, the species can be found in five different biomes including the Amazon, Atlantic Forest, Caatinga, Cerrado, and Pantanal. However, jaguar populations in each of these biomes are under different types and levels of threat.

During the Jaguar National Action Planning Workshop, a red listing exercise was performed with workshop participants and discussed in plenary sessions. Results from this work are presented in a series of articles in this issue. All the rules and definitions in the IUCN Red List Categories and Criteria Version 3.1 (IUCN 2001) were applied to jaguar populations in each Brazilian biome where they occur. Given that individuals can move between biomes, methods for adjusting the results were applied using the IUCN Red List Regional Guidelines (IUCN 2003).

There are important reasons to assess the risk of species extinction at the biome level. Using ecological borders rather than geo-political is often more efficient in terms of conducting explicit practical conservation assessments. In the case of jaguars, the biome-based assessment clearly illustrated how populations in different biomes where under different threats and at varying levels of extinction risk. Results from this exercise were important in assessing populations within each biome and to pinpoint areas where information lacked. The Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), an agency of the Brazilian Environmental Agency (IBAMA), is currently assessing species throughout Brazil and is now using the jaguar workshop and process as a model to adopt a biome approach for the red list assessment of other wide-ranging species.

An action plan must also be based on sound conservation science and during the Jaguar National Action Planning Workshop three different modelling tools were used which are further detailed in this issue. A Population Viability Analysis (PVA) exercise took place to explore jaguar population dynamics and better gauge potential management scenarios and conservation strategies. In addition, the species distribution was modelled through the use of GIS and an environmental suitability map for jaguar distribution was created. Finally, priority areas for jaguar conservation and parameters important for building a corridor model to identify connections between source populations also took place in working groups during the workshop.

The purpose of this publication is to inspire other groups preparing their action plans on methods, tools and techniques that can be successfully applied. We hope you enjoy this issue and look forward to sharing results from the implementation of this action plan in the coming years. An action plan is only successful if it is widely implemented for the conservation of species and their habitats.

Arnaud Desbiez and Christine Breitenmoser-Würsten

ARNAUD L. J. DESBIEZ[1] AND ROGÉRIO C. DE PAULA[2]

Species conservation planning: the jaguar National Action Plan for Brazil

A species conservation plan provides a detailed proposal of actions that need to be undertaken to "save" a species. A species action plan must be based on sound conservation science and prepared through an inclusive, participatory process. The Jaguar National Action plan took place in Atibaia, São Paulo, Brazil in November 2009. It was organised and funded by CENAP (Centro Nacional de Pesquisa e Conservação de Mamíferos Carnívoros, the government organization responsible for all aspects of carnivore conservation, research and policy making), Pro-Carnivoros (a national carnivore NGO) and Panthera (an international felid NGO). The Brazilian Network of the IUCN/SSC Conservation Breeding Specialist Group (CBSG) together with the IUCN/SSC Cat Specialist Group (CatSG) designed and facilitated the workshop.

During four days 35 participants (Fig. 1) including biologists, representatives from governments, protected areas, NGOs, zoos, universities, and landowners worked together to produce an action plan who's main objective was to "Reverse the trend of jaguar population declines in each of the five biomes where the species is encountered and reduce the category of threat in each biome in the next 10 years". The workshop design was inspired by a mix of methods developed by the IUCN/SSC CBSG, CatSG as well as the specific demands of the workshop organisers. During the workshop a national action plan for jaguars was created, a status review of each jaguar population from the five biomes (Fig. 2) was assessed, a Population Viability Analysis model produced and various scenarios run based on Vortex (Desbiez et al. 2012, this issue), habitat suitability model was created to map the distribution of known and potential jaguar populations using Maxent (Ferraz et al. 2012, this issue) and corridors and main Jaguar Conservation Units (JCUs) were updated (Nijhawan 2012, this issue).

Fig. 1. Workshop participants in Atibaia in November 2009 (Photo B. Beisiegel).

Jaguars are the most studied felid in the Neotropics and their historical and current distribution has been well mapped compared to other species (Sanderson et al. 2002). The IUCN/SSC approach to species conservation planning requires a status review of the species be performed before the action plan is created. A different participatory approach for the status review was adopted. For each of the biomes in which jaguars occur a 'biome leader' was identified and a detailed questionnaire based on the information necessary to categorize a species according to the IUCN Red List criteria was sent. The biome leader consulted with all experts in his/her region to compile the necessary data. The information was compiled and analyzed before the workshop using IUCN Red List Criteria (IUCN 2001) at the regional level. In this case each biome was considered a region. Results from the biome assessment and level of threat of each jaguar population were then presented during the workshop. Participants as well as the models developed during the workshop helped to complete each assessment which are presented in this issue. On the day before the workshop started, the organising committee and the IUCN/SSC CBSG/CatSG met throughout the morning and early afternoon to iron out last minute details and run through the program. Participants began arriving in the afternoon. Everyone was accommodated in the location where the workshop took place. The workshop facilities included a large plenary meeting room as well as six smaller rooms in which smaller working groups could convene. All rooms had plenty of wall space to hang sheets from the flip charts and electrical outlets for computers. The opening ceremony took place in the evening, followed by a general presentation on jaguars and people, then participants gathered for a welcoming cocktail. Action planning workshops are working meetings rather than symposia and are not the appropriate venue for lengthy presentations or research program updates. No project up-date presentations by researchers or other such presentation were scheduled. Participants were warned about this and were encouraged to e-mail their reports and information before or after the workshop or leave hard copies for participants at the workshop (two participants chose to do this). The full four days of the workshop were dedicated to working on the action plan and models.

Workshop dynamics included splitting the group of participants into topic-based working groups and reconvening in plenary sessions to present results from working group deliberations and stimulate discussions. Working groups then registered the comments made in plenary. In this way every participant had the chance to give his/her opinion on all aspects of the workshop. During the plenary sessions presentations to guide the work as well as updates on biome red listing, population modeling, distribution maps and JCUs were given. Work on the models and biome red listing was done after-hours (Fig. 3) or exceptionally some participants were pulled out of a group to work on one of the topics. For both the population modeling and the red listing, questionnaires had been sent to participants two months before the workshop. Data and results had been analyzed, written up and were submitted to workshop participants for comments and approval.

One of the group's first activities on the first morning was to generate working group topics. After presenting him/herself each participant stated what he/she thought were some of the most important conservation threats to jaguars. Threats were listed on cardboard papers and set on a sticky wall. Threats were consolidated and six topic based working groups were created: Habitat loss and Fragmentation, Human/jaguar conflicts, Hunting, Education and Communication, Public policies, and Research.

A topic based approach was selected over a biome working group approach to ensure maximum exchange of experience and perspectives during the workshop. On the last day in the afternoon biome groups were formed in which participants could select and rank what they thought were the most important conservation targets for their biome.

Before breaking into working groups a plenary session exercise was organized for the participants to agree on a sentence expressing the main purpose of the action plan (stated above). Small groups, which merged into larger groups and then the full plenary created a vision of what they hoped the action plan would achieve. This final vision stated the purpose of the workshop was to "Reverse the trend of jaguar population declines in each of the five biomes where the species is encountered and reduce the category of threat in each biome in the next 10 years". This vision did not incorporate human values or the relationship between jaguars and people even though this was discussed at length.

Fig. 2. Biomes of Brazil. The jaguar occurs in all of them exept in the Pampa.

Step by step working groups set out to analyze the root of the problems facing the species, set conservation objectives and finally develop detailed conservation actions. Each working group brainstormed on all potential problems and their causes. The analysis was focused on priority issues and identifying the root causes of each problem. Clear problem statements were written. Once these problem statements were written and reviewed in plenary, working groups developed objectives to address the stated problems. Short and long term objectives were compiled, and after approval in plenary, actions to accomplish each objective were written up in detail. Each action included: 1) a short statement which can be understood by a non-participant reader, 2) the name of individuals responsible for organizing or monitoring the progress of each action, 3) a time line was set, potential collaborators listed, 4) resources needed mentioned and 5) indicators for monitoring purposes listed. In each working group CBSG facilitators used and shared with participants a diversity of tools and methods to help participants during each of these steps. The result presented in general plenary was a list of 69 objectives and 174 actions (Table 1).

Posterior to the workshop, organizers performed a consolidation of Problems, Objectives, and Actions, aiming a better understanding for policy makers, decision takers, and general readers. No change on the proposed actions was made. Problems, Objectives and Actions were mostly merged to facilitate the implementation. The final action plan resulted on 46 objectives and 167 actions after consolidation (Table 1). The final objectives are listed by theme as presented by the working groups:

Table 1. List of problems, objectives and actions identified in each working group (a. before organizers consolidation; b. after consolidation).

Working group	Problems	Objectives	Actions
Communication and education	5[a]/6[b]	16[a]/13[b]	37[a]/31[b]
Public Policies	7[a]/7[b]	12[a]/11[b]	27[a]/27[b]
Research	13[a]/4[b]	20[a]/4[b]	45[a]/43[b]
Habitat loss and fragmentation	7[a]/6[b]	7[a]/6[b]	20[a]/20[b]
Hunting	5[a]/5[b]	6[a]/5[b]	13[a]/13[b]
Conflicts	5[a]/5[b]	8[a]/7[b]	32[a]/33[b]
TOTAL	**42[a]/33[b]**	**69[a]/46[b]**	**174[a]/167[b]**

Fig. 3. Participants of the Jaguar Conservation Workshop in Atibaia, São Paulo state, Brazil, in November 2009 (Photo R. C. de Paula).

A) Communication and Education

1. To spread information on jaguar conservation and preventive methods for livestock depredation to ranchers, farmers, people living within jaguar distribution range, in schools of rural areas, and in technical rural schools and to landowners in 10 years.
2. To implement communication and educational programs based on jaguar conservation for traditional local populations in 2 communities per biome in 7 years.
3. To create and implement educational programs based on jaguar conservation in all the captive institutions maintaining the species in 3 years.
4. To inform the regulations of tourism activities based on jaguar observation to tourism entrepreneurs in 3 ½ years.
5. To have tourism enterprises incorporating educational proposals and basic information on jaguars in 3 years.
6. To inform the negative impacts of inappropriate practices of jaguar tourism based on observations in 3 years.
7. To establish partnerships between educators and conservationists in 2 years.
8. To have educational projects aiming jaguar conservation elaborated by educators in at least one research project per biome in 6 years.
9. To have the general society aware of jaguar conservation problems in 4 years.
10. To reduce the social motivation to jaguar persecution and poaching in 4 years.
11. To have conservationists recognizing the importance of communication and using it as a tool for conservation in 2 years.
12. To publish the scientific findings in popular 'language' in 5 years.
13. To create and maintain a press office within the agency responsible for jaguar conservation in 2 years.

B) Public Policies

1. To have the Brazilian Government recognizing the jaguar as symbol for national biodiversity conservation in 3 years.
2. To have financial government resources set specifically for research and conservation of jaguar and its habitats in 5 years.
3. To implement the use of all possible government conservation tools (map of priority areas, national species action plans, protected areas management plans, economic-ecological zoning, etc.) in all government decisions (approval of large entrepreneurs, protected area creation, etc.) in 2 years.
4. To manage regional policies according to the biome specificities and jaguar conservation needs in 5 years.
5. To define and establish rules for the sustainable extraction of renewable natural products in 2 years.
6. To define aggregation values to sustainable extracted renewable natural products and farming and ranching products with low impact to the environment and to the jaguar populations.
7. To integrate research institutions, funding agencies, government, and non-government institutions on the execution of jaguar conservation actions in 5 years.
8. To elaborate a protocol of procedures to communicate and direct to the inspecting agencies the action and/or programs to enforce the legislation related to jaguar conservation.
9. To manage along to the Judiciary a plan to promote an effective punishment to environmental crimes.
10. To elaborate funding proposals for thematic projects through a network of jaguar researchers and institutions.
11. To establish rules for the tourism involving jaguar.

C) Research

1. To attend the lack of knowledge through research and to have these information constantly updated in 10 years for the following: demographic aspects (density estimates and mortality, dispersal, and birth rates); social structure; health parameters; reproductive biology (especially litter size, age of first female breeding, fecundity, mortality in the first year); interpopulation gene flow; genetic variability; habitat use and trophic ecology.
2. To evaluate and monitor impacts and threats to jaguar populations (specially related to the habitat loss and fragmentation, epidemiology and toxicology) in at least one population per biome in 10 years.
3. To survey and evaluate the socio-environmental and economic variables leading into jaguar-human conflicts in 5 years.
4. To increase the collaboration and exchange of information among several actors performing important role on jaguar research and conservation in 10 years.

D) Habitat loss and fragmentation

1. To identify and make official the jaguar priority areas in 1 year.
2. To identify and indicate at least one area per biome (under the pressure of deforestation and extraction of renewable and non-renewable natural resources) to propose the creation of protected area of full protection, within the polygons of priority areas.
3. To maintain or re-establish gene flow among isolated jaguar populations as well as populations that have reached a critically small size.
4. To avoid or mitigate the impact of human occupation within the jaguar priority areas.
5. To reduce or compensate the environmental impacts in areas of influence of energetic entrepreneurs (dams, wind fields), within the jaguar priority areas.

6. To reduce mortality rates of jaguars and prey species from habitat loss related to roads construction, road killing, and burns within the jaguar priority areas.

E) Hunting

1. To create a database (constantly updated) containing technical and scientific information on hunting occurrence (local x regional, temporal frequency), its types (sport-hunting, subsistence, retaliation, etc.), the impacts on jaguar populations, impacts on prey species, the relative importance of local hunting in each biome/region for jaguar conservation, in 8 months.
2. To fill the knowledge gaps on poaching/hunting through increasing research and publications specifically on hunting occurrence (local x regional, temporal frequency), its types (sport-hunting, subsistence, retaliation, etc.), the impacts on jaguar populations, impacts on prey species, the relative importance of local hunting in each biome/region for jaguar conservation, in 10 years.
3. To increase and improve the law enforcement capacity within the official agencies in 10 years: by increasing the number of agents, by improving infrastructure and logistics, by providing specific training, by increasing the operational patrolling area through network operations, and to make it feasible a support from trained civilians.
4. To increase the number of protected areas and to increase the size of areas already under protection where jaguars have been confirmed within 10 years.
5. To gradually increase the public awareness about biology and ecology of jaguars and prey species in 10 years.

F) Conflicts

1. To reduce the number of individuals removed due to real or supposed livestock depredation in 10 years.
2. To create a network for the stakeholders involved in jaguar conflicts in 2 years.
3. To have tourist activities related to jaguars regulated and monitored, and to create economic benefits to motivate the proper management in 10 years.
4. To enforce the control and to raise efficiency on the combat for decreasing jaguar persecutions and removals in 5 years.
5. To identify, quantify and qualify the causes of removals of young jaguars in each biome in 3 years.

Table 2. Reference table for the monitoring of the implementation of the NAP.

Not attended Not initiated	Just initiated	Partially attended Ongoing	In final stage	Accomplished concluded
0%	1-33%	34-66%	67-99%	100%
0	1	2	3	4

6. To elaborate destination protocols to removed animals in 1 year.
7. To elaborate studies of rehabilitation and reintroduction viability for jaguars in 10 years.

The objectives were ranked for each biome among the 69 proposed for the entire country ending in a maximum number of 10 objectives listed per biome. The list of the priority objectives is listed below based on the objective number within each working group:
Amazon: D4, C1, A1, B3, E2, B7, F2, B10
Caatinga: C1, A8, A1, E5, B4, F1, C3, D5, B1
Cerrado: C1, F1, D2, D3, D5, B2, E3, B10, C2
Atlantic Forest: C1, E3, F1, D3, B3, B9, A9, D4, E4, D2
Pantanal: B4, D4, A1, E3, C1, B6, F1, F3, E2
A proposal for implementation of the action plan was presented and discussed in the final general plenary, on the last day of the meeting together with the presentation of a suggested working group to support the implementation committee. The committee is composed of a general supervisor, an assistant and a working (support) group composed of the coordinators of each working group topics and coordinators for each biome. Thus, the implementation committee includes a total of 13 people. The NAP supervisor has the function of evaluating the general implementation through the updates of the working group and biome coordinators. Each coordinator will track the implementation state of each action by liaising with the person named as the articulator for this action during the workshop. The implementation will be monitored following the time line proposed for the actions and the accomplishment will follow the indicators proposed. The implementation was planned following the guidelines below:
1. The implementation monitoring will be conducted following a reference table (Table 2). The numerical classes synthetize the implementation status of an action.
2. Annual meetings of the implementation committee will keep the working group coordinators attentive to deadlines and to necessary change adjustments or even delays in the action when necessary;
3. The elaboration and presentation of annual reports based on working group themes and biome updated implementation reports;
4. Maintain a regular information flow to both the participants of the NAP and jaguar stake holders;
5. Observation and articulation of actions to improve the effectiveness of the implementation of actions common to themes and biomes;
6. Maintain constant communication among all involved partners for a successfull implementation of the NAP.

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Red List assessment of the jaguar in Brazilian Amazonia

Amazonia is the most important biome for the long-term survival of the jaguar in Brazil due to its relatively well preserved state and continuous area of adequate habitat. In the Brazilian portion of Amazonia the jaguar's present extent of occurrence EOO continues to encompass the whole area of the biome, but the continued loss of habitat in the east and southeast limits of this biome, an area known as the "arch of deforestation", has resulted in a significant reduction and fragmentation of the jaguar's area of occupancy AOO. Based on data from camera trap surveys we assumed an average density of 1-2 jaguars/100 km^2 for the majority of the biome, with the exception of well-preserved floodplain forest areas where the species is more abundant. Considering this average density, the effective population size to total population size ratio proposed by Frankham (1995, 2009), and the total remaining area of the biome, we estimated the present effective jaguar population size for Amazonia in Brazil to be < 10,000 individuals. In addition the jaguar population is likely to be decreasing in this biome as a result of habitat loss, direct persecution and depletion of prey population. In our evaluation the jaguar should be classified as Vulnerable C1.

Assessment

Vulnerable – Due to the ongoing loss of habitat, substantial poaching of jaguars and their prey, and the fragmentation of populations across portions of its range, and an expected population of mature breeding individuals of <10,000 this species is considered to be Vulnerable (VU C1) in Amazonia.

The Amazon is the most important area to consider for successful long-term jaguar conservation worldwide. Amazonia is a vast biome and includes the most extensive areas of suitable and non-fragmented habitat available to this large felid (ca. 5,300,000 km^2, Soares-Filho et al. 2006). The Amazon Basin represents approximately 70% of the species' total area of occurrence and also serves to connect populations from other important ecosystems (Sanderson et al. 2002, Zeller 2007). Approximately 3,459,000 km^2 of all of Amazonia (ca. 65%) is located in Brazil. Thus, it is possible to conclude that the Brazilian Amazon harbours the largest jaguar population worldwide (Seymour 1989).

In Brazil, jaguar populations are classified under different conservation categories because they face different types and levels of threats (from Vulnerable to Critically Endangered). Even inhabiting such a huge area, the jaguar population in Amazonia is estimated at <10,000 mature individuals, based on the effective population size to total population size ratio proposed by Frankham (1995, 2009), which, in association to habitat loss and its expected population loss, made jaguars be considered Vulnerable (VU C1).

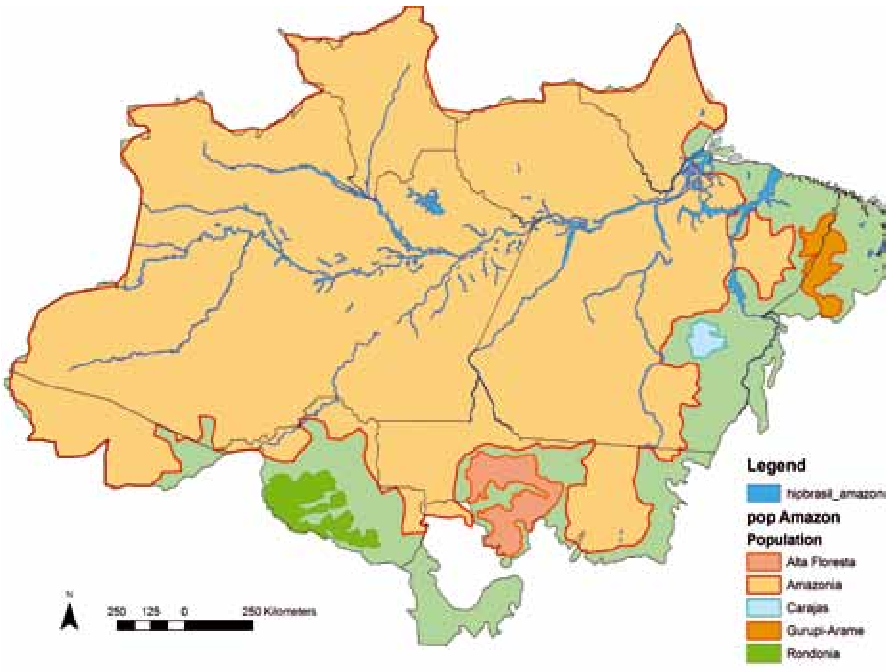

Fig. 1. Jaguar area of occupancy and potential sub-populations in the Brazilian Amazon.

Geographic range

Extent of occurrence EOO

The current extent of occurrence of jaguars in Amazonia still includes the entire basin, as it has historically. During the "Jaguars in the new millennium" workshop held in Mexico in 1999, which resulted in the species' range extension map that is currently being used (Sanderson et al. 2002), it was noted that there is a huge gap in a major portion of the central-southern part of Amazonia in Brazil. This gap is primarily due to a significant lack of knowledge about the area and not to the actual absence of the species, as there are valid records of its occurrence from this region (Ferraz et al. 2012, this issue).

Area of occupancy AOO

The area of occupancy for jaguars in Amazonia is basically all of the basin where natural cover still remains and where the species has not been extirpated due to hunting, a threat mostly presented by conflict with the interests of cattle rancher. This means that the species has mostly disappeared from parts of what is known as the "deforestation arch", which essentially borders the eastern and southern limits of the area. More specifically, this "arch" includes eastern and southern Pará, western Maranhão, northern Mato Grosso and Rondônia. According to INPE's estimates, the total deforested area of the Brazilian Amazon is 733,321 km^2 (INPE 2010), or about 18.4% of the originally forested area.

Within most of the area, there still appears to be a single, large panmictic population. However, along the deforestation arch, habitat fragmentation and isolation of small populations has already begun. The most immediate effects of fragmented habitat are likely to be the functional isolation of populations in the areas of Gurupi (W-Maranhão and E-Pará), Carajás (SE-Pará), SW-Rondônia, and NE-Mato Grosso from the main population of Amazonia (Fig. 1).

In the forested ecoregion of the Tocantins River in eastern Amazonia, which includes

E-Pará and W-Maranhão, jaguars have disappeared from the seasonally flooded fields of Baixada Maranhense, an area that is similar to the Pantanal in this respect, and from the deforested areas of these states (T. G. de Oliveira, pers. comm.). In other parts of the deforestation arch, the species' area of occupancy has also been considerably reduced because of habitat destruction, and in some cases further amplified by poaching and direct conflict with cattle ranchers. For example, this difficult situation has been observed in the regions of Alta Floresta-MT (Michalski et al. 2006) and Bico do Papagaio-TO/PA/MA (Oliveira 2002, T. G. de Oliveira, pers. comm.).

Ecology and population information
Population size

The Amazonian jaguar population is thought to have a high probability of survival (Sanderson et al. 2002), and is considered as something like an insurance policy for the long-term persistence of the species. There are only two population estimates for jaguars in the Brazilian Amazon available at this time. One population estimate comes from the Mamirauá Sustainable Use Reserve, an area of várzea forest at the confluence of the Amazon and Japurá Rivers, where the population density was calculated to be 10/100 km^2 (Ramalho 2008). This very high density is likely due to the relatively high productivity of várzea forest and the large population of caimans, which are the jaguar's main prey item in Mamirauá (Ramalho 2006). In Cantão State Park, which is a transitional area between the Amazon and Cerrado biomes, jaguar population density was estimated to be 2.58/100 km^2 (Astete 2008). None of these areas are like the typical terra firme forests that characterize most of the Amazon area, so these estimates cannot be considered as representative of the entire region and, thus, do not facilitate a realistic estimation of the species' population size for the whole biome.
In the Bolivian Amazon, jaguar density at Madidi National Park was estimated to be 2.84/100 km^2 (Silver et al. 2004), whereas in the Colombian Amazon, densities were estimated to be 4.5/100 km^2 in Amacayacu National Park and 2.5/100 km^2 in unprotected areas (Payan 2008).
Sollmann et al. (2008) extrapolated from the estimate of Silver et al. (2004) for the protected areas where jaguars are found in the Brazilian Amazon and calculated a population size of 51,920 individuals. Given the high degree of variability in habitat quality and anthropogenic threats within the Amazon basin however, it is unreasonable to expect a single population estimate from the Bolivian Amazon to be representative of the entire biome in Brazil.

Fig. 2. Jaguar camera-trapped in the várzea forest of Mamirauá Sustainable Use Reserve (Photo E. E. Ramalho).

Population density in terra firme forests in Brazil is estimated to be 1-4/100 km^2, with a mean of 1-2/100 km^2, or even lower in areas with less suitable habitat. Following an approach similar to that of Sollmann et al. (2008), but using the species' occurrence adequacy modelling in the biome (Ferraz et al., in prep.) and taking into account the areas that are currently deforested (INPE 2010), the expected mean density, and the effective population size, these results would be quite different. We considered two estimates of the effective population size, one less conservative (i.e., Ne = 0.4N; Nowell & Jackson 1996) and the other more restrictive, having been based on genetic factors applied to big felids and other top predators (Ne = 0.1N; Frankham 1995, 2009). By this approach, we get an expected population size ranging from 10,580 to 21,160 jaguars (the less conservative estimate), or of only 2,645–5,290 individuals (the genetically based estimate), that are effectively contributing to the gene pool in all of the Brazilian Amazon. When we consider extinction risk analysis, the total population size (N) is of little use and can even give us a false sense of security. What really matters is the number of individuals that effectively contribute to the gene pool, i.e., the effective population (Ne; Frankham 2009).
Using the same procedures and the same density estimates, but also considering the area of remaining natural vegetation capable of supporting jaguar populations and accounting for dispersal throughout the entire biome (cut of 2-37, see Nijhawan et al. 2012), the effective population size estimate is 14,974-29,948 (less conservative Ne) and 3,744-7,487 (genetically based Ne) mature individuals. It is important to emphasize that all of the estimates presented here are merely speculative and do not take into account an array of important factors to consider, including the great degree of habitat heterogeneity in the region. It is crucial that data from more direct methods (e.g., camera trapping) be obtained from several areas of the Brazilian Amazon before a reasonably accurate estimate for jaguar populations can be proposed.
Jaguar populations throughout the deforestation arch are being seriously depleted and animals are already being extirpated from some areas (Michalski et al. 2006, E. Carvalho Jr., pers. comm., T. G. de Oliveira, pers. comm.). However, given the previous estimates, the size of the area and expected density, the effective population size for the Brazilian Amazon is estimated to be above or below 10,000 mature individuals, depending on Ne estimator. This projection essentially renders the Amazonian population as the jaguar stronghold and underscores its importance to the long-term survival of the species.
Taking into account the population estimates for Cerrado and, especially Atlantic Forest

Fig. 3. Burning forest along the deforestation arch in southeastern Pará (Photo. T.G. de Oliveira).

and Caatinga biomes (see Amorim Moraes Jr 2012, Beisiegel et al. 2012, de Paula et al. 2012, all this issue), would make jaguars Vulnerable worldwide. However, this has not happened because of the enormous size of Brazilian Amazonia, which favours the persistence of viable effective populations of greater than 10,000 mature individuals.

Seven Jaguar Conservation Units (JCUs) were established for the Brazilian Amazon at the "Jaguars in the New Millennium Workshop" in 1999, but these were re-evaluated, increased in size and reduced in numbers during the 2010 Brazilian Jaguar Population Habitat Viability Analysis Workshop (Nijhawan 2012, this issue).

If the scenario for future environmental degradation that was presented by Soares-Filho et al. (2005, 2006) for 2050 proves to be accurate, it is likely that jaguar populations in Amazonia will be restricted to the proposed JCUs. This would be the case because these JCU's were delineated based not only on the presence of protected areas and their eco-regional importance, but also on predictions for habitat loss (Soares-Filho et al. 2005, 2006). Population estimates for these areas are presented in Table 1.

Population trends

The jaguar population appears to be declining throughout much of its range where human presence is greater, due primarily to higher levels of habitat destruction and the hunting of jaguars and their prey (Silveira et al. 2008, R. C. de Paula, pers. comm., T. G. de Oliveira, pers. comm.). Unfortunately, due to a lack of formal research, there is no valid quantitative data to corroborate this assumption. The population decline in Amazonia is probably much higher along the deforestation arch, where it is known that the species has already disappeared from several areas where it used to occur, which can safely be inferred from knowledge of the high rate of deforestation and from various sources of indirect evidence (Michalski et al. 2006, E. Carvalho Jr., pers. comm., T. G. de Oliveira, pers. comm.). Taking the Bico do Papagaio region (which occurs in the border area of Pará, Tocantins and Maranhão), where there are high levels of deforestation and hunting pressure both on jaguars and their prey (observed over a 13 years period from 1997 to 2009) as an example, signs of the presence of jaguars declined abruptly (T. G. de Oliveira, pers. comm.). This tendency could be confirmed at Alta Floresta (MT), where the mean rate of large cat removal was found to be 0.56 animals/100 km^2 of remaining forest, which is a significant portion of the large felid population in the area (Michalski et al. 2006).

The rate of deforestation in Amazonia has fluctuated since 2000, from -31 to +18%, or a mean annual rate of -0.875% (INPE 2010). In this way, areas subjected to greater degrees of human pressure, notably those areas most impacted by urban sprawl, cattle ranching, agriculture and industrials activities, the jaguar population is markedly declining. In areas with less anthropogenic pressure, population declines appear to be more moderate while in the more isolated and pristine areas it may be assumed to be more or less stable.

Subpopulations

Satellite images of the remaining vegetation cover in Amazonia (INPE 2010) show that there is some degree of connectivity among most areas. As such, there do not appear to be any completely isolated jaguar populations in the Brazilian Amazon just yet. However, given the current trends of habitat loss and fragmentation that are being observed throughout the region, it is not unreasonable to predict the existence of one core population and 4–5 subpopulations sometime in the future (Fig. 1).

Considering the scenario where certain subpopulations become isolated, and applying certain of the population parameters used in Vortex to model extinctions (see Desbiez et al. 2012, this issue), such as 12 individuals being lost to hunting every two years (except in the case of the Carajás subpopulation where the hunting rate is six animals/2 years), the overall probability of extinction varies from 17% to 99% (Table 2). If we apply a scenario where habitat loss over a 20 year period occurs at a rate of 2%/year for the Carajás and Rondônia subpopulations and 3% for the Alta Floresta and Gurupi-Arame subpopulations (following their mean annual deforestation rate), the probability of extinction would be 100% for each of these subpopulations, except for Carajás (Table 2).

Table 1. Expected population of mature jaguars that would be contributing to the genetic pool of the important Jaguar Conservation Units in Amazonia, considering population densities between 0.01 – 0.02 individuals/km^2.

Parameter	JCU 1	JCU 2	JCU 3	JCU 4	JCU 5
Area (km^2)	1,686,246	417,681	12,131	37,940	93,080
Expected effective population (N_e = 0.4N) minimum – maximum	6,745 – 13,490	1,671 – 3,341	49 – 97	152 – 304	372 – 745
Expected effective population (N_e = 0.1N) minimum – maximum	1,686 – 3,372	418 – 835	12 – 24	38 – 76	93 – 186

Other life history information

Even the most basic information on jaguar biology in Amazonia is scarce, as very few studies have yet to be conducted (e.g., Emmons 1987, 1989, Kuroiwa & Ascorra 2002, Silver et al. 2004, Payan 2008). In Brazil, besides a couple of studies on population parameters (Astete 2008, Ramalho 2008), the only life history investigations have been conducted at Mamirauá (Ramalho 2006, Ramalho & Magnunsson 2008) and in a transitional area between Amazonia and the Cerrado (Nuno 2007). In the seasonally flooded, várzea forests of the Amazon River basin, high jaguar population density estimates and numerous records of mothers with cubs at the Mamirauá Reserve, suggests that várzea habitat could be very important to the species for successful reproduction in Amazonia (Ramalho 2008; Fig. 2). In this ecosystem, during the dry season (where the forest floor is completely exposed) the main prey species of jaguars are spectacled and black caimans *Caiman crocodiles* and *Melanosuchus niger*, sloths *Bradypus variegatus* and howler monkeys *Alouatta seniculus*. Among these prey items, the spectacled caiman is the most important in terms of both frequency of occurrence and biomass (Ramalho 2006). This suggests that jaguar conservation planning in the seasonally flooded forests of the Amazon should be directly associated with caiman conservation efforts. No studies have been conducted yet to determine which species are jaguar prey during the wet season, but field observations at the Mamirauá Reserve indicate that jaguars tend to prey more upon arboreal mammals during the flooding period (E. Ramalho, pers. comm.). Observations from the mangrove forests of the Maracá-Jipioca Ecological Station (Amapá state) suggest that, during the progression of the dry season, jaguars tend to concentrate around the disappearing muddy ponds where catfish become isolated, and take full advantage of this abundant and easily obtained resource. Other prey species that are known to be consumed by jaguars include white-tailed deer *Odocoileus virginianus*, agoutis *Dasyprocta agouti* and capybaras *Hydrochaeris hydrochaeris*, but not feral buffalos *Bubalus bubalis* (T. G. de Oliveira, unpubl. data). At Cantão State Park (TO), a transitional area between Amazonia and the Cerrado, jaguar prey varied, but in terms of biomass, larger prey (> 10 kg) such as peccaries *Tayassu spp.*, tapirs *Tapirus terrestris*, and cattle predominated (Nuno 2007).

Fig. 4. Rice fields at the Gurupi Biological Reserve. Eastern Amazonia is becoming a new frontier for agriculture (especially soybean) following the boom and decline of timber exploitation.

Threats

The major threats to jaguars in Amazonia are habitat loss, habitat fragmentation and hunt-ing of both jaguars and their prey (see Supporting Online Material SOM Table 1 at www.catsg.org/catnews). Jaguar population declines in Amazonia are noticed especially where human encroachment is greatest, notably along the deforestation arch. In most of this area jaguar populations have been severely reduced or extirpated due to a combination of habitat loss, hunting of their preferred prey and predator removal (Oliveira 2002, Michalski et al. 2006). Historically, the major threat was poaching for the skin trade.

Habitat loss

Habitat loss is the most serious threat to the Amazonian jaguar population and, thus, to the long-term survival of the species. The total area deforested in Amazonia reached 733,321 km^2 in 2008 (i.e., 17.6%, INPE 2010), or about the size of Turkey. The rate of habitat loss has also fluctuated considerably over the years (Fig. 3). Between 1989 and 2009 it was estimated at 17,743 km^2/year, with a slight increase after the year 2000, to 18,650 km^2/year (INPE 2010).

Although considerable tracts of land are protected as preserves, sustainable use areas or indigenous reservations, future conservation scenarios are grim. Recent models predict that up to 40% of Amazonian forests will be lost by 2050 (Soares-Filho et al. 2006). Most protected areas are essentially just 'paper reserves', with little to no direct management or enforcement of the law. Some of these areas, which are under very restrictive categories, also have human settlements inside of their boundaries, causing both direct habitat loss and habitat degradation. Such is the case of the Gurupi Biological Reserve.

Habitat loss in Amazonia is mostly due to cattle ranching, but is increasingly more related to large-scale agriculture (Soares-Filho et al. 2006). There is also a potentially large amount of habitat loss due to land usage and development associated with the roads being paved across the region (Soares-Filho et al. 2005). Typically, after timber resources are totally depleted in an area, the degraded forest is then cleared for pasture or agriculture (Fig. 4). It has been observed, however, that jaguars will use forest that has been heavily disturbed by timber exploitation, as long as there is a suitable prey base (Oliveira 2002).

Hunting

In the 20th century, especially during the 1960s, the greatest threat to jaguars in Amazonia was hunting for the skin trade (Smith 1976, Oliveira 1994, Nowell & Jackson 1996). During that time, it has been estimated that more than 15,000 jaguars were killed for their pelage every year in Brazil (Smith 1976). This threat was ameliorated in Brazil, for the most part, through the Federal Protection of Fauna Law in 1967 (Lei Federal 5197/67) and the inclusion of jaguars in Appendix I of CITES. These measures made jaguar hunting and commercialization illegal in Brazil and internationally.

Table 2. Expected population parameters and probability of extinction of predicted jaguar sub-populations in Amazonia after 100 years.

Parameter	SW-Rondônia	NE-MT – Alta Floresta	Carajás PA	Gurupi/ Arame MA
Area size – km^2	48,678	67,292	12,940	34,746
Expected density N/km^2	0.01	0.01	0.03	<0.01
Expected total population size – N	487	673	388	347
Expected effective population – N_e	195	269	155	139
Without Deforestation				
Probability of extinction	84%	17%	18%	99%
Final genetic diversity (%)	0.94	0.97	0.92	0.91
Number of jaguars after 100 years	626	930	201	136
With Deforestation (per 20 years)	*2%*	*3%*	*2%*	*3%*
Probability of extinction	100%	100%	45%	100%
Final genetic diversity (%)	0	0	0.90	0
Number of jaguars after 100 years	0	0	130	0

Nowadays the hunting of jaguars is due mostly to conflicts with ranchers who lose livestock to predation, and the occasional killing due to the fear of attack on humans and 'sport' hunting. The hunting threat varies in intensity throughout the Amazon basin, but is nevertheless prevalent anywhere there is cattle ranching activity. Eastern Amazonia and the deforestation arch can be considered areas of medium to high conflict (Oliveira 2002, Michalski et al. 2006, Boulhosa & Michalski 2009). There has been no accurate mapping of the most critical areas of conflict along the deforestation arch. However, Michalski et al. (2006), based on interviews with landowners in Alta Floresta (MT), reported an alarming number of 110-150 jaguars and pumas (combined) having been killed within a one year period due to conflicts with ranchers. We believe that throughout all of the deforestation arch, from Rondônia to Maranhão, the increasing contact between farmers and jaguars is directly proportional to the increase in conflicts and, consequently, in jaguar mortality due to retaliation. We speculate that this trend might intensify from west to east, reaching the highest levels in eastern Pará and western Maranhão. Therefore, unlawful predator removal could pose a significant, if not the most significant cause of jaguar mortality in these areas. In Amapá, an important area for jaguar conservation because of its extensive system of protected areas, excessive hunting due to livestock depredation represents an inferred decrease in population. There are even several municipalities (Amapá, Tartarugalzinho, Ferreira Gomes) where there are expert jaguar hunters who can be hired to kill problem animals. According to interviews with local people in these areas, an average of one jaguar is killed every month (R. C. de Paula, pers. comm.).

Jaguar hunting in Amazonia goes on virtually unnoticed by authorities, with very few cases actually reported, a situation that could be attested to several sites (T. G. de Oliveira, pers. comm., CENAP, unpubl. data). Hunting of jaguars does not seem to compromise population stability within protected areas (Ramalho & Carlos 2010), the opposite of what is observed in the most impacted/fragmented areas, close to or far from protected areas (Oliveira 2002, Michalski et al. 2006). New studies are desperately needed to assess the different impacts of hunting on jaguar populations within Amazonia.

Reduction on the prey base

Loss of the prey base is often associated with both cattle ranching practices as well as with other forms of human encroachment in Amazonia. The loss of prey should be more pronounced in the most fragmented and human influenced areas, such as in Eastern Amazonia and along the deforestation arch in Rondônia and Mato Grosso. The prey species most often taken by humans are the same as those that are preferred by jaguars (Jorgenson & Redford 1993, Oliveira 1994). This exploitative competition between humans and jaguars is most detrimental to the latter. Field observations have been showing that jaguar occurrence in fragmented areas and places disturbed by logging seems to be more associated with the loss of the prey base than it is to habitat degradation (Oliveira 2002, T. G. de Oliveira, pers. comm.). The combined effect of habitat loss and fragmentation, and the hunting of prey, associated or not with livestock conflicts, would lead to the local disappearance of jaguars in several areas.

Conservation information

At least two large blocks of interconnected protected areas could help guarantee the long-term persistence of genetically viable jaguar populations under a scenario of complete isolation in the Brazilian Amazon. One such area is "Calha Norte", which is centered around the Montanhas do Tumucumaque National Park (Amapá/N-Pará), and includes 63,000 km^2 of protected land (part of JCU-1). The other area is southwestern Pará, which includes a mosaic of protected areas around Terra do Meio, and includes 77,220 km^2 of protected land (part of JCU-2).

It is important to mention the large mosaic of protected areas in the State of Amapá, which are functionally connected to the great Calha Norte corridor, thus forming JCU-1. This state network of protected areas serves as refugia for jaguars. The Amapá Biodiversity Corridor, which is ca. 100,000 km^2, connects 12 different state and federally protected areas, consisting of both totally protected and sustainable use areas. Included among these areas there are Montanhas do Tumucumaque and Cabo Orange National Parks, the Maracá-Jipioca Ecological Station, and the Lago Piratuba Biological Reserve. Unfortunately, with the exception of the first park, illegal jaguar hunting has been observed in all of them.

Calha Norte, in conjunction with the Biodiversity Corridors of Amapá and Central Amazonia, with a total area of 363,000 km^2, would represent the most important area for jaguar conservation worldwide. However, deforestation modelling for Amazonia until 2050 (Soares-Filho et al. 2005, 2006) suggests that the western portion (closest to the border of Brazil with Venezuela, Colombia and Peru) will represent the largest continuous block of natural areas for jaguars if the predicted deforestation scenario prevails. As the delineation of the current JCU's considered not only the presence of protected areas, but also the likelihood of deforestation, it is reasonable to assume that these areas could act as mega-areas/reserves and ensure the long-term persistence of viable jaguar populations. With regard to the mosaic of protected areas including Terra do Meio in central and southwestern Pará, jaguars were not readily recorded throughout all of the preserves. At some of these preserves, such as the Terra do

Meio Ecological Station, Rio Pardo National Park, and the Altamira National Forest, there are reports of jaguar hunting, mostly due to conflicts with cattle ranchers (Beisiegel 2009, Paula & Lemos 2009). In Amazonia in general, wherever there is a significant number of livestock and environmental degradation (e.g., in the deforestation arch), there are bound to be conflicts with humans that are detrimental to the jaguars.

Considering just those preserves that are totally protected from human exploitation, their combined size alone is considerable in Amazonia. However, their actual effectiveness remains questionable, as most are paper reserves. Because the Amazon is the main stronghold for the species, and given the enormous area requirements of jaguars (Oliveira 1994), it is of paramount importance to secure the connectivity between protected areas in the basin, so that their size may be large enough to guarantee the long-term conservation of viable jaguar populations. Effective management and law enforcement in protected areas is also important.

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The jaguar in the Atlantic Forest

Jaguars *Panthera onca* are Critically Endangered (A4 b c d; C2 a i) in the Atlantic Forest because a population reduction of 50-90% was estimated in the past 10-15 years in the largest subpopulations of jaguars at the Upper Paraná and is suspected at the Coastal Atlantic Forest. The causes of reduction have not ceased since there is a continuous decrease in the Extent of Occurrence EOO, Area of Occupancy AOO and habitat quality, plus retaliatory and sport killing. The total number of mature individuals is less than 250 and the number of mature individuals is less than 50 in almost all subpopulations. The most serious threats to jaguars in the Atlantic Forest are habitat loss and degradation, loss of prey base and jaguar hunting. Legal protection has been ineffective in stopping Atlantic Forest deforestation and most protected areas have human settlements, causing direct habitat loss, habitat degradation and loss of prey base; other forms of habitat degradation are caused by illegal palm *Euterpe edulis* harvesters and poachers, as well as through natural and criminal fires that occur throughout the Atlantic Forest. Conservation measures most needed are the legal and effective protection of all the remaining large fragments of the Atlantic Forest through new restrictive Conservation Units, restoration of connectivity between the extant protected areas with known jaguar populations, effective protection of the extant Conservation Units in the form of intensive patrolling and an increase in ecological and genetic research to allow population management, which may be a necessity in some areas.

Assessment

Critically Endangered A4 b c d; C2 a (i) – A population reduction of at least 50%, probably closer to 87-90%, was estimated in the past 10-15 years in the largest subpopulations of jaguars at the Upper Paraná. The main cause of reduction of this subpopulation in the past 25 years may have been habitat loss which has intensified in the region in the last 60 years; therefore, a similar trend of subpopulation reduction may be suspected to have occurred in the last 25 years. The causes of reduction have not ceased since there is a continuous decrease in the extent of occurrence EOO, area of occupancy AOO and habitat quality, plus retaliatory and sport killing; therefore the trend of reduction of the subpopulation in the Upper Paraná is likely to continue for the next 25 years and the species may become extinct in 88 years. There is no long-term information for subpopulations in the coastal Atlantic Forest, but the reduction of the EOO to 43% at the south of the Serra do Mar range which occurred over the last 50 years, the ongoing habitat loss and the habitat quality degradation which is increasing throughout the Atlantic Forest support the supposition that population losses and trends are similar to those on Upper Paraná or worse. The total number of mature individuals is less than 250 and the number of mature individuals is less than 50 in almost all subpopulations with the exception of one subpopulation estimated at 52 mature individuals.

Geographic range information

Extent of occurrence EOO

The Atlantic Forest originally occupied 1,315,460 km^2 (IBGE 2008) and jaguars were historically distributed throughout the biome (Sanderson et al. 2002). The present extent of occurrence EOO of jaguars in the Atlantic Forest is 44,487 km^2. It comprises both the protected areas with known or inferred recent (last 10 years) jaguar presence (Table 1) and points of jaguar presence reported by researchers and in the literature. This EOO represents 44% of the remaining 102,012 km^2 (INPE & SOS Mata Atlântica 2008) of the Atlantic Forest and is divided in eight polygons which also represent present jaguar subpopulations (Fig. 1). A single Minimum Convex Polygon is not adequate to represent jaguar EOO because the areas with jaguar presence in the Atlantic Forest are isolated by large areas unsuitable for jaguar presence (Ferraz et al. 2012, this issue) which occupy ca. 80% of the EOO.

The Atlantic Forest may be divided in 15 ecological regions (Di Bitetti et al. 2003). In regard to jaguar distribution, the Upper Paraná Forest Ecological Region located west of meridian 51 represented by polygons 1 and 2 in Figure 1 differs from the remaining Atlantic Forest not only by ecological but also socio-economic characteristics and threats to the conservation of the species.

Area of occupancy AOO

Jaguars use mainly good quality habitat (Cullen et al. 2005) which is almost totally confined to the interior of protected areas (Fig. 2). Thus, the area of occupancy AOO of jaguars in the Atlantic forest is 30,382 km^2, which is the sum of the Conservation Units with known or inferred recent jaguar presence (Supporting Online Material SOM Appendix 1).

Fig. 1. Extent of occurrence EOO of jaguar in the Atlantic forest. The numbers refer to the polygons described in Table 1.

Severe fragmentation

The massive destruction of the Atlantic Forest began with the European colonization (Dean 1996) and has greatly accelerated in the last three decades (INPE & SOS Mata Atlântica 2008) with a mapped destruction of 11% of the remaining forest from 1985 to 1995 (Câmara 2005), allowing a projection of roughly 27% loss in the past 25 years. Despite legal protection, Atlantic Forest deforestation continues at an average rate of 350 km²/year (INPE & SOS Mata Atlântica 2008), which projects to a loss of 8.5% of the remaining forest in the next 25 years.

The smallest of the isolated forest fragments with recently confirmed jaguar presence is the 360 km² PE Rio Doce (Viana 2006). According to Ribeiro et al. (2009) only around 20% of the remaining forest exists in fragments larger than 250 km². The Atlantic Forest is the most densely populated area of Brazil and the areas between the subpopulations are intensely occupied by human activities. Although jaguars have good dispersal ability (Quigley & Crawshaw 2002), most of these occupied areas are totally unsuitable for jaguar use; therefore, the eight subpopulations are isolated from one another.

In the Upper Paraná only 2.7% of the original forest area remains (7,712.76 km², Di Bitetti et al. 2003). The occupation of the region was intensified around 60 years ago initially by coffee and cotton plantations and subsequently by cattle farms and the cultivation of other crops (Godoy 2001).

The marshland areas of the Paraná River which represent 40% of the habitat suitable for jaguars available in the Upper Paraná are being destroyed by hydroelectric dams. Presently only 30% of the Paraná River in Brazil is free of dams and the marshlands of the River Paraná have been reduced to 230 km² (Agostinho & Zalewsky 1996).

Ecology and population information

Population size

Population estimates for the Upper Paraná have been obtained by radio telemetry and camera trapping in different environments and areas. In PE Morro do Diabo population density was 2.22 ind./100 km² (Cullen et al. 2005); in PN de Iguaçu, Brazil, 15 years ago population density was 3.7 ind./100 km² (Crawshaw Jr 1995); in PN Iguazú, Argentina, contiguous to PN Iguaçu in Brazil, population densities were 0.49 ind./100 km² and 0.93 ind./100 km² when this Park is added to private contiguous areas (Paviolo et al. 2008). Preliminary data from the "Projeto Carnívoros do Iguaçú" corroborate the low population density found by Paviolo et al. (2008) in the Iguaçu region. In marshland areas such as the PE das Várzeas do Rio Ivinhema a population density of 0.72 to 0.84 ind./100 km² was estimated (D. Sana, unpubl. data). Except for the PE Morro do Diabo, the recent studies have estimated low population densities - smaller than 1 ind./100 km² in all regions.

Cullen (2006) estimated a carrying capacity of around 82 animals for the region of PE Morro do Diabo, PE das Várzeas do Rio Ivinhema and PN de Ilha Grande. From PE Morro do Diabo to PN de Iguaçú along a 50 km strip of each side of the rivers Paranapanema and Paraná, there are around 13,000 km² of adequate habitat for jaguars consisting of forests and marshlands. When marshland and forest areas with different population densities were separated, a carrying capacity of 94 individuals was estimated for this region (Programa "Onças do Alto Paraná" unpublished data). However, there are important contiguous areas at Paraguai and Argentina (Missiones) at the Green Corridor which add protected areas

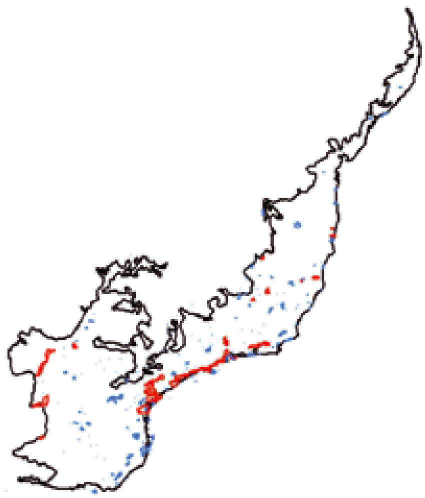

Fig. 2. Area of occupancy AOO of jaguar in the Atlantic Forest, estimated as the protected areas (red lines) with known or inferred presence of the species.

Table 1. Estimated extent of occurrence EOO of jaguar and population size (mature individuals) estimated for the 8 subpopulations of the species in the Atlantic Forest.

Polygon	Polygon #/ Subpopulation	States	area (km²)	# mature individuals	References and methods
PN Iguaçu to PE do Turvo	1	RS, SC, PR, Misiones (Argentina)	4,542	32	Paviolo et al. 2008, camera-traps
Pontal do Paranapanema to PN Ilha Grande	2	PR, MS, SP	9,517	52	Cullen et al. 2005, camera traps; Sana, unp. data, radio telemetry and camera traps
Serra do Mar	3	PR, SP, RJ	25,609	31-51	Beisiegel & Oliveira, unpubl. data, camera-traps
Sooretama/Reserva Vale	4	ES	2,514	<20	Srbek-Araujo, unp. data, camera-traps
Mantiqueira	5	MG	828	6	Amorin Jr., unp. data, camera traps
Rio Doce	6	MG	365	13	Viana 2006, camera traps
Espinhaço	7	MG	154	1	Amorin Jr., unpubl. data, camera traps
Monte Pascoal/Pau Brasil	8	BA	958	1 - 5	Leite et al. 2002
Total			**44,487**	**156 - 180**	

Fig. 3. View of Parque Estadual Carlos Botelho PECB, inside the best preserved forest in the Serra do Mar polygon (Photo B. Beisiegel).

suitable for the species. These areas must also be considered for the conservation of jaguars (Paviolo et al. 2006). The population densities cited above allow the estimate of 32 mature animals for the polygon of PN Iguaçu to PE do Turvo and 52 mature individuals for the polygon of Pontal do Paranapanema to PN Ilha Grande.

The core area population of the Serra do Mar polygon lies within the southwestern portion of São Paulo state and adjacent areas of Paraná state where due to low socio-economic development human pressure on the forest is less accentuated than in the remaining Atlantic forest. At the fragment including the Parques Estaduais Carlos Botelho, Intervales and PETAR, which is the best preserved portion of this forest, jaguar population density is 0.23-0.39 mature individuals/100 km^2 (B.M. Beisiegel & E.N.C. Oliveira, unpub. data). The Area of Occurrence of jaguars in this polygon is 13,147.79 km^2; if jaguar population density was uniform through all the area, the Serra do Mar polygon would have a total population of 30 - 51 mature individuals. However, most of the Area of Occurence in this polygon is not so well preserved as in the Park. Tracks and reports suggest that in most of its areas jaguar population density is much lower that at PECB; therefore, the best estimate for this polygon would be less than 51 individuals.

Fig. 4. Interior of the Atlantic forest in Parque Estadual Carlos Botelho PECB (Photo B. Beisiegel).

The Reserva Vale area has a population of less than 20 mature individuals (A.C.S. Araujo unpublished data); and although there are no data from Reserva Biológica Sooretama, the same individuals probably use both areas. The best population density estimate for the polygons of the Minas Gerais state (Parque Estadual do Rio Doce, Mantiqueira and Espinhaço) are 0.02 ind/100 km^2 in suitable areas of, respectively, 1,253.65, 605.86 and 139.42 km^2 (Viana 2006; E.M. Amorin Jr., unpubl. data). Leite et al. (2002) estimated the population of south Bahia state to be 3-9 jaguars of which 1-5 would be mature individuals; but there is no present information on its status or persistence.

The total jaguar population for the Atlantic Forest is therefore no greater than 156-180 mature individuals. Table 1 summarizes subpopulation estimates.

Population trends

Jaguar subpopulations are declining throughout the Atlantic Forest. At the Green Corridor including the Iguaçu National Park in Argentina and Brazil jaguar population densities decreased 2-7.5 times over 10 years (Paviolo et al. 2008) indicating a 50% to 87% population reduction in this period. Preliminary studies of the Project "Carnívoros do Iguaçu" indicate that the population density at PN do Iguaçu may be 10 times lower than the density estimated by Crawshaw (1995) 15 years earlier and that implies a 90% population reduction over this period. If the present trends of reduction and isolation of subpopulations continue, the average time for the extinction of the jaguar at the Upper Paraná is estimated to be 88 years (Cullen et al. 2005).

The species disappeared from the Coastal Atlantic Forest of the States of Rio Grande do Sul and Santa Catarina between the years 1960 and 1990 (Mazzolli 2008) which means a loss of more than 20,000 km^2 and a reduction of 43% of the EOO of jaguars at the southern portion of Serra do Mar over 30 years.

Human occupation of the areas surrounding the AOO of jaguars and human pressure inside the Conservation Units are increasing. Consequently habitat quality and capacity for the support for jaguar subpopulations is decreasing.

Subpopulations
In the Upper Paraná (polygon 1 and 2 in Fig. 1) jaguar subpopulations are restricted to semi-connected areas in a metapopulation structure (Cullen et al. 2005). Genetic studies denote 4 groups: Morro do Diabo; Porto Primavera; Ivinhema and Green Corridor (PN de Iguaçu to PE do Turvo, connected by forest area in Missiones, Argentina (Haag 2009). Loss of genetic variability and isolation between these areas may be occurring, with the Green Corridor being isolated from the subpopulations in the north (Haag 2009).
There are at least six subpopulations within the Coastal Atlantic Forest (Table 1). Since there is no evidence of connectivity between PN Serra da Bocaina and REBIO Tinguá (RJ), the Serra do Mar subpopulation may also be separated in two.


Fig. 5. Large scale habitat loss in the Parque Estadual do Turvo to gain land for agriculture (Photo B. Beisiegel).

Other life history information
Inside any remnant of the Atlantic Forest, 12 km is the maximum distance from any non-forested area (Ribeiro et al. 2009); and this distance, which is similar to the average jaguar home range diameters (8.55 km^2, Crawshaw 1995) occurs only within the largest remnants. Therefore, probably only a few jaguars in all the Atlantic Forest have home ranges free from edges with non-forested, populated areas.

Threat information
Being the top terrestrial predator throughout its range, the jaguar is affected by all threats that decrease the populations of their prey in addition to the threats specific to their own survival. SOM Appendix II presents these threats according to the IUCN classification scheme and the most serious of them are discussed here.

Habitat loss
Legal protection of the Atlantic Forest has been ineffective in stopping deforestation. Moreover, most protected areas including the most restrictive categories have human settlements, causing both direct habitat loss and habitat degradation.

Habitat degradation
This is one of the most serious threats faced by the species since carrying capacity determines the impact of small population sizes on population growth, long term persistence, genetic diversity and mean time to extinction (Desbiez et al. 2012, this volume). All the protected areas of the Atlantic Forest suffer from some form of habitat degradation, mainly the activities of illegal palm *Euterpe edulis* harvesters and poachers which cause loss of prey base and alteration of the forest ecology. The marshland areas of Upper Paraná are annually affected by natural and criminal fires.

Loss of prey base
Subsistence and sport hunting occurs throughout the Atlantic Forest. In some localities jaguar prey, mainly tapirs *Tapirus terrestris*, white lipped peccaries *Tayassu pecari*, different deer species *Mazama spp*. and collared peccaries *Pecari tajacu* have been overhunted to scarcity or extinction (Crawshaw 1995, Cullen et al. 2000, Azevedo & Conforti 2008).

Jaguar hunting
In some parts of the Atlantic forest the rarity of the jaguar today is probably due to elimination of the species in the past. Such is the case in the Serra do Mar from southern RJ (PN Serra da Bocaina; P. Crawshaw, pers. comm.) to the PE da Serra do Mar where there is plenty of the preferred jaguar prey and continuous forest cover (A. Rossi, pers. comm.).
Retaliatory killing occurs throughout the Upper Paraná where there is a predominance of cattle farms (D. Sana, unp. data, IBAMA, unp. reports, Crawshaw Jr. 1995, Azevedo & Conforti 1999) and in the southwestern São Paulo state (e.g. Palmeira & Barrela 2007). Sport hunting is not cited in the literature but is reported by researchers and by the staff of some protected areas (APA de Guaraqueçaba, EE Xitué, PE Intervales).

Conservation information
Conservation measures
SOM Appendix III presents current projects on jaguar conservation. Here we list the most pressing conservation actions needed to conserve the jaguar in the Atlantic Forest.

1. The jaguar needs legal protection in the form of restrictive Conservation Units for all the remaining large fragments of the Atlantic Forest, and restoration of connectivity between the extant protected areas with known jaguar populations.
2. The species needs effective protection of the extant Conservation Units in the form of intensive patrolling. This is regarded as one of the most important conservation measures by the collaborators of this account and by the literature (e.g. Mazzolli 2008).
3. There is a need to increase ecological and genetic research to allow population management. Translocations to increase depleted populations or to reduce inbreeding may be a necessity in some areas (e.g. Sooretama/Reserva Vale complex, A. C. Srbeck-Araujo, pers. comm., north coast of São Paulo, A. Rossi, pers. comm.).

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Supporting Online Material SOM Appendices I to III are available at www.catsg.org/catnews

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Red List assessment for the jaguar in the Caatinga Biome

The Caatinga is the only exclusive Brazilian Biome and the jaguar *Panthera onca* is one of the most endangered species in this biome. In this paper we present the status of the species in the Caatinga biome. No specific information on jaguars' biology and ecology is available for the Caatinga. Jaguars are distributed within the Caatinga along 178,579 km², which represents 21% of the biome. This range was estimated based on the confirmed locations, population ranges, and the favourable areas for its presence based on habitat viability models. It seems that the jaguar population in the biome is very fragmented. Five sub-populations were identified and the area of occupancy of jaguars was 87,325.50 km². This area comprises only 10% of the total area of the Caatinga biome. The general average of all the density estimates resulted in a number of 0.3 individuals/100 km², a very low population with estimation of 262 individuals. The status of conservation of jaguar is Critically Endangered C2 a(i). Among the main threats to its populations are stern fragmentation, habitat loss and degradation, loss of prey base, jaguar hunting, and industrialization of the surrounding areas. Some conservations measures like maintenance of the gene flow among jaguar populations by means of ecological corridors and a new protected area are urgent actions.

Assessment

Critically Endangered C2 a (i) – The total number of mature individuals is less than 250 and the number of mature individuals in each subpopulation is less than 50 in the majority of the subpopulations.

Geographic range

Extent of Occurrence (EOO) and Area of Occupancy (AOO)

The Caatinga comprises a total of 844,453 km² throughout ten northeastern States (IBGE 2004). Although the presence of jaguars *Panthera onca* within its boundaries has been controversial, it remains one of the most threatened species in this biome. Until recently the extent of occurrence in the biome was uncertain due to the lack of information and almost the entire Caatinga was indicated as an area of unknown status (Sanderson et al. 2002). Studies over the past ten years by several researchers made the calculation of a distribution range for Caatinga recently possible for the first time. The jaguars are distributed over 178,579 km² which represents 21% of the biome (Fig.1). This range was estimated based on confirmed locations (research projects and specific investigations), population ranges, and favourable areas for its presence based on habitat suitability models (Ferraz et al., in prep.). Within this range 35,668 km² represent 17 protected areas. These areas are key zones for jaguar conservation in this biome since the suggested causes of population decline are directly or indirectly generated by human presence.

Little information on jaguars is available in the Caatinga. Five subpopulations were defined based on location groupings and inferences of suitable habitat. The Area of Occupancy of jaguars in the Caatinga is the sum of the subpopulations. Therefore, the total of the jaguar's area of occupancy is 87,325.50 km² which represents 49% of the jaguar distribution range and only 10% of the total area of the Caatinga biome.

Severe fragmentation

Most of the Caatinga (68%) is disturbed by anthropogenic factors (MMA 2002) and only 31.6% remains intact. Present jaguar distribution is related to the remaining natural habitat quality which depends on reduced human presence and activity. The area along Sao Francisco River in Bahia state represents one of the sectors with the highest human pressure (MMA 2002). Consequently, the human development index increased substantially in the same area (da Silva et al. 2004). Implications for jaguar conservation are clear since they no longer are present in areas of high human development.

Human density in Caatinga generally is very low - averaging 50 to 100 people/km². Within the jaguar range the average is lower than 50 people/km² (da Silva et al. 2004). However, human settlements are abundant; ranging from less than 50 inhabitants to towns with ca. 50,000 people (Fig. 3). Considering that game hunting for food and cultural purposes remains widespread and an important aspect of the local lifestyle, the number of settlements as well as the size of human populations plays an important role in jaguar conservation.

Ecology and population information

Population size

Jaguar population has never been estimated systematically in this biome. The only published information is very recent (Silveira et al. 2010) from research on population estimates in the Serra da Capivara National Park. Since 2005 CENAP has additionally been survey-

Fig. 1. Estimated Extent of Occurrence EOO in the Caatinga.

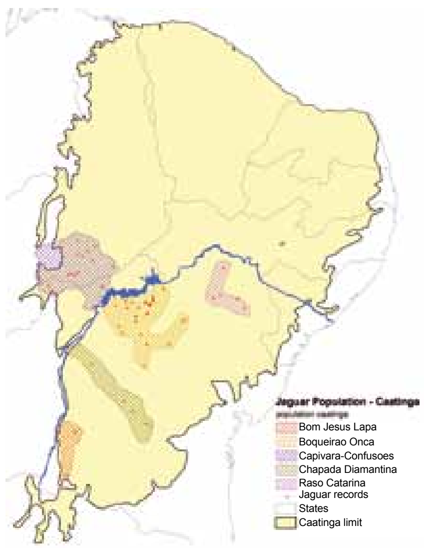

Fig. 2. Area of Occupancy AOO of jaguar in the Caatinga (polygons of estimated subpopulations).

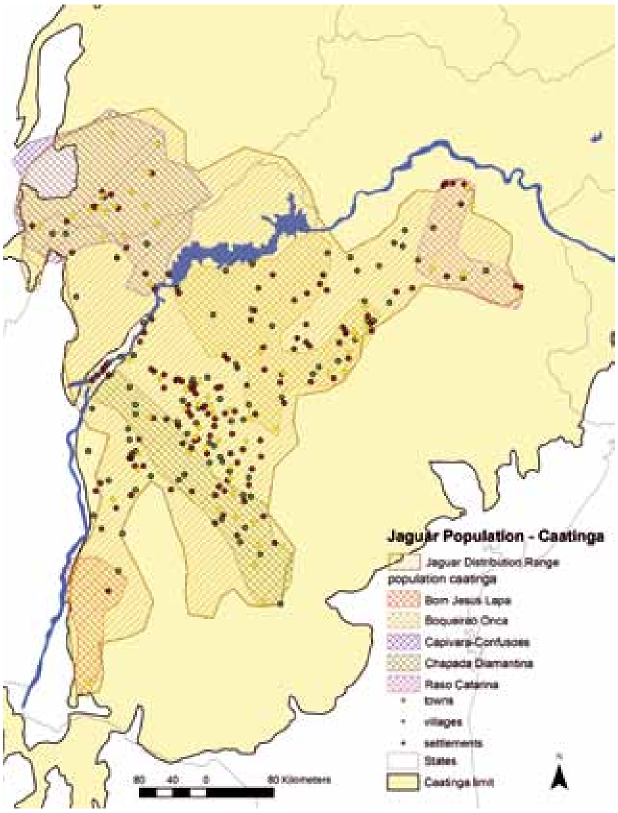

Fig. 3. Human encroachments within the Caatinga's jaguar distribution range.

ing the region of Boqueirão da Onça in Bahia state. Subpopulation estimates (Table 1) were based on the estimates from Boqueirão da Onça associated with researchers' perceptions from field research of sites surveyed for local jaguar abundance and more importantly from the variations of the suitability model (Ferraz et al., in prep.).

The densities were directly calculated for the sites where population information was available from camera trapping. Research conducted by CENAP (unpubl. data) found a density estimate of 0.8 ind./100 km^2 at Boqueirão da Onça (Subpopulation 1). Based on this information and investigations in the rest of the subpopulation area an average of 0.5 ind. /100 km^2 was calculated considering the proximity of highly disturbed adjacent areas with lower jaguar density.

The density estimates reported by Silveira et al. (2010) does not reflect the reality of jaguar populations in the Caatinga; the evaluation at Serra da Capivara National Park (at Subpopulation 2) presented a density estimate of 2.67 ind./100 km^2. The estimate in this particular area cannot be observed in any other site within the jaguar range nor even for the entire Subpopulation 2 itself, but only for the Serra da Capivara National Park due to the specific management activities the area has. The management strategies applied to this protected area, which includes year-round water supplies (through artificial ponds) and increased patrolling and law enforcement to reduce hunting activities, provides a different reality for wild populations of this location, resulting in a higher abundance of prey species for predators. The proper management confers a more suitable area for jaguars. Considering the specificity of estimates for the particular site, we propose for Subpopulation 2 the same average density estimate as we used for Subpopulation 1 (0.5 ind./100 km^2). This estimate was used since the habitat suitability index and numbers of records were very similar (except for the deforestation rates that are higher in the southern portion of this subpopulation). Despite the differences especially in the research protocols and data analysis, the values accounted perhaps are really discrepant (maybe it would not be three times as a standardization in the analysis would reduce the difference). The first site is a National Park that has been managed as described above. Although the second site (Boqueirão da Onça) has a very low human density (in average <1 person/km^2) resulting in one of the most extensively preserved portion of natural habitats in the entire biome, there is still prey hunting and predator persecution on a large scale. However, undoubtedly these two are the main areas (together with the Serra das Confusões National Park) for jaguar conservation in the entire biome.

No research project or specific investigation was conducted in Subpopulation 3 with the exception of CENAP's camera trapping at Chapada Diamantina National Park. From this sampling over 60 days no jaguar was detected. Despite the significance of protected area status, a more conservative density estimate for this subpopulation was considered due to the human occupation in most of its area. Thus we defined it as 0.3 ind. /100 km^2. Although this subpopulation is more isolated than the subpopulations 1 and 2, a connection can be established between it and 1 if changes in land use are applied.

For the Subpopulations 4 Raso da Catarina and 5 Bom Jesus Lapa located in the extremes of the range, the density estimates reflect the worst case scenario and are 0.2 ind./100 km^2 and 0.1 ind./100 km^2, respectively.

The general average of all the density estimates resulted in 0.3 ind./100 km^2, a very low density when compared to other biomes that range from 2 (for Cerrado, Silveira 2004) to approximately 6 individuals/100 km^2 (Pantanal, Soisalo & Cavalcanti 2006).

Table 1. Jaguar subpopulations and density estimates in Caatinga.

Subpopulation	**1**	**2**	**3**	**4**	**5**
	Boqueirão da Onça	**Capivara – Confusões**	**Chapada Diamantina**	**Raso da Catarina**	**Bom Jesus Lapa**
Density (ind/100km^2)	0.5	0.5	0.3	0.2	0.1
Area (km^2)	25,560.4	30,938.5	16,464.6	7,872.3	6,490.7
# of mature individuals	64	78	25	8	3

Subpopulations

The jaguar population in Caatinga is very fragmented. This led us to define the jaguar distribution into five subpopulations (Table 1). If connectivity exists between subpopulations, it will be restricted to only three of them: 1 Boqueirão da Onça with 2 Capivara-Confusões, and 1 with 3 Chapada Diamantina. But the connections between these three subpopulations must be investigated. The Subpopulations 4 Raso da Catarina and 5 Bom Jesus Lapa are definitively isolated from the main block (1, 2, and 3) by human development. There are no records of connectivity between these two and the other subpopulations.

Subpopulation 1 – Boqueirão Onça

This is the second most important area for jaguar in Caatinga. Although it has only three protected areas (the Morro do Chapéu State Park, the Gruta dos Brejões and the Lago do Sobradinho Environmental Protection Areas), it is one of the most continuously preserved areas of the Caatinga. This characteristic made the creation of the Boqueirão da Onça National Park with nearly 8,000 km^2 possible (Fig. 4). This subpopulation was scientifically discovered only in 2005. It was subject to pelt trade for decades until the mid-1990s. Currently animals are persecuted due to livestock losses. The increase in mining activities (Fig. 5) as well as other development related to energy generation and agribusiness pose a major threat to jaguar conservation.

Due to intense human development to the south and east of this subpopulation, there is a strong belief that this subpopulation does not connect with the Subpopulations 3 and 4. On the other hand potential connectivity exists with Subpopulation 2. Although the São Francisco River forms a natural barrier, during the dry season sandbanks exposed in the middle of the river might allow dispersers to cross in the southern end of the subpopulation. The possibility of even a temporary connection between subpopulations would sustain both subpopulations for longer periods since both areas are the most suitable ones for jaguars in the biome and the range.

Subpopulation 2 – Capivara-Confusões

This subpopulation defined by the boundaries of the Serra da Capivara and Serra das Confusões National Parks as well as the Serra Branca Ecological Station between them is the most important for jaguar conservation in Caatinga. This is the subpopulation that

Fig.4. Aerial view of Boqueirao da Onça habitat during the wet season (Photo R. C. de Paula).

will connect with the Cerrado's subpopulations which are not in as critical condition as the Caatinga's. Jaguar records in this area are mainly located in the protected areas and their boundaries. However the species was detected in areas near the São Francisco river (south of Sobradinho lake) which confirms the potential connection with Subpopulation 1.

In contrast to the subpopulation across the river, the jaguars in this area are mainly threatened with habitat loss due to deforestation for the supply of the charcoal industry (Fig. 6) and conversion of natural areas into agricultural fields. Approaching the Cerrado biome (2/3 of the Serra das Confusões National Park are within the Cerrado's boundaries), habitat alteration becomes more severe. One of the most threatening factors for this subpopulation is the locally heavy prey base hunting and the persecution of predators due to livestock losses.

Subpopulation 3 – Chapada Diamantina

This subpopulation is sustained mainly by the southern portion where the Chapada Diamantina National Park is located. The subpopulation also encompasses the Lagoa Itaparica and Marimbu-Iraquara Environmental Protected Areas. Little is known about jaguar status in this subpopulation. The known information is restricted to isolated records from livestock conflicts. Persecution due to these conflicts and habitat alteration are the major threats for this subpopulation.

Subpopulations 4 – Raso da Catarina and 5 – Bom Jesus Lapa

These subpopulations are small and totally isolated from the others; jaguar records are rare and most are related to livestock conflicts. Both subpopulations have a high probability to disappear in short time if persecution or habitat loss become more severe.

The three records obtained in 2007 demonstrate the vulnerability of Subpopulation 5: if it becomes totally isolated it will likely disappear in the short-term. However, there are

Fig. 5. Increasing mining activities in the Caatinga are destroying important jaguar habitat (Photo C. Campos).

Fig. 6. Deforestation for charcoal production is an important threat to jaguars in the Caatinga (Photo C. Campos).

records of jaguars in adjacent subpopulations of the Cerrado population to the south and west. If Subpopulation 4 effectively connects with the Cerrado's subpopulations, then it can survive for longer periods. On the other hand the Subpopulation 4 is totally isolated by a barrier of human development from mining companies, federal highway construction and agricultural activity between this subpopulation and the 1.

Population trends

The Caatinga's jaguar stable population was believed to be restricted to Subpopulation 2 (Capivara-Confusões) until records over the past ten years indicated other possible sites (Boqueirão da Onça and Morro do Chapéu regions). The Chapada Diamantina National Park and Raso da Catarina Ecological Station were considered potential areas of occurrence; but specialists doubt whether or not jaguars consistently occupy these areas due to the few recent records of its presence. Little research has been conducted in the Caatinga in general and specially with an elusive mammal such as the jaguar. The only area where jaguars have been studied is the Serra da Capivara National Park. Astete (2008) discussed several aspects of a possible increase in jaguar numbers following an observed increase in prey abundance. The author based his comparisons on research reported by Wolff (2001) in the same area. It looks as if management practices such as increasing park patrols and enforcement have successfully inhibited prey loss due to local hunting activity. Water ponds maintained by the park during the dry season have apparently attracted and possibly increased both predator and prey numbers. Data from the mid-1980s indicate an estimate of 6 jaguars in this same protected area. However past research did not evaluate directly the jaguar population in the same way as Astete (2008). This later scientific data indicated an estimate of at least 21 individuals.
Considering the two decades of improved management and the information available, the park's jaguar population shows an increase of about 200%. Even in the only area with study results, population trend data is not robust. On the other hand, local people's perceptions indicate that there is a decline in the jaguar population in the majority of the subpopulations due to hunting for the pelt trade until the mid-1990s and the persecution due to livestock losses. Scientific information is required in order to have a better understanding of population trends.

Extreme fluctuations

Although apparently no immediate impact causes extreme fluctuations presently, the São Francisco River transposition has been suggested by specialists as one of the main environmental disasters of the century in Brazil since the damage will affect the entire watershed. The vegetation of Caatinga which is adapted to long dry seasons nonetheless depends on the water supplies even if it is in small quantities (Vicente et al. 2003). A detour of the main water body in the entire biome would significantly alter the hydrodynamics in the local watersheds and consequently affect local habitat. By having a drastic impact on vegetation, especially in the composition of forested areas, the suitable habitat for jaguars in the future could be significantly reduced and consequently cause extirpation of smaller subpopulations or extreme fluctuations of Caatinga's populations.

Other life history information

Jaguars apparently show a strong preference for dense vegetation cover in Caatinga and this habitat is restricted to only a few preserved areas throughout the entire biome. Further information is required in order to understand more life history information.

Threats

Jaguar population decline can be caused by habitat loss due to constant disturbance and fragmentation (Sanderson et al. 2002). Conflict with humans due to livestock depredation and the resulting jaguar persecution can also be a cause of decline (Cavalcanti 2003). Both are the main causes affecting jaguar conservation in the Caatinga.

Habitat loss

About 27 million people currently live in the biome, where 70% of the original vegetation has been altered. Human population density is homogeneous, occurring at levels below 100 hab./km^2 (Sampaio & Batista 2004). A large portion of this population bases its survival on natural resources.
About 7% of the biome is covered with PAs. The conservation of these areas is intimately related to efforts that prevent desertification, a serious condition of the semi-arid areas of Caatinga. The deforestation and the maintenance of irrigated cultures accelerate the desertification process by inducing soil salinization. In Brazil 62% of the areas susceptible to desertification are located in the Caatinga, and large portions of these are significantly altered by deforestation or natural habitat conversion into agriculture fields (MMA – SRHPB 2007).
The identification of reserves of iron and other minerals including precious stones in some regions of Caatinga is worrisome because of potentially devastating extraction methods. Charcoal has been extracted quite intensively

in some regions, resulting in large deforested areas due to the lack of sustainable management and law enforcement.

Habitat alteration
Historically, the agriculture practiced in the semi-arid region is nomadic, itinerate or migratory. Farmers in this region remove natural vegetation, use fires and cultivate the soil for a short period. However, due to a lack of planning tradition, agricultural practices end up being a source of disorderly territorial occupation causing highly negative impacts on the environment (MMA 2002). Within the last decades, important changes have remodeled the territorial reality of the northeast, altering the characteristics ot the man-nature relationship of the region (MMA 2005).
New agricultural technologies developed to overcome difficulties such as the low water availability and intense heat characteristics of the Caatinga, have enabled the growth of areas exploited not only for agriculture but also for livestock production. In the western portions of the biome the growth of areas cultivated with soybeans and other monocultures threaten the transition areas of Caatinga-Cerrado.

Loss of prey base
Wildlife hunting for subsistence is culturally significant throughout the Caatinga (Coimbra Filho et al. 2004). This has critical implications for the conservation of many species, since local populations have been decreasing at alarming rates. Several species such as armadillos, peccaries, deer and agoutis among others are targeted by hunters. Although there is a lack of a detailed study on wildlife hunting in the Caatinga, local residents perceive a reduction in abundance of the overhunted species in several areas. Although these prey species are well distributed within the biome, their excessive hunting can drastically reduce populations within a few years, if education and law enforcement strategies are not implemented.

Jaguar hunting
Currently the majority of jaguar hunting incidences in the Caatinga are related to retaliation for livestock depredation. Several individuals are also killed during opportunistic encounters with hunters in search of other species. According to some local residents' accounts jaguar numbers in the region were considerably larger 30-40 years ago than they are now. It was common for hunters to return from their hunting ventures with more than one dead jaguar. At the time the demand for jaguar pelts was high especially for sales to Western Europe (Broad 1988). At present, albeit to a lesser degree, there still exists the demand for jaguar skins (Fig. 7) by large entrepreneurs visiting some of Caatinga's regions.

Locations
The habitat alteration or loss and consequently its fragmentation poses major threats for the jaguar population and their distribution in the Caatinga. The two southern areas of the jaguar range (Subpopulations 3 and 5; Fig. 3) present an accelerated degree of habitat disturbance due to the expansion of agribusinesses. The first doesn't contain any protected area, and it is already being widely exploited for agriculture, cattle ranching, tourism and fishery. The proximity of several mineral deposits increases the underground mining enterprises in the Capada Diamantina area with gold, diamond, emerald and other precious stones, marble and others being extensively extracted. The search for more sources of minerals is attracting more exploration and enterprises to this area with uncontrolled extraction, a constant threat due to ineffective law enforcement. The increasing of mining activities can also be observed in the area of the Subpopulation 1. More recently, the energy companies became interested in this area as well because of its potential for wind power.
The presence of highways with intense traffic to the south and east of Subpopulation 1 can be a threat to the distribution of the species, further isolating this important subpopulation from other potential areas.
In the northwest (Subpopulation 2) there are three nearby protected areas which are however discontinuous. The jaguar dispersal could be guaranteed with the viability of natural corridors that would guarantee individual movement. However, predators moving through human land might cause additional conflict when the scarcity of food leads jaguars to prey upon livestock. Conflicts between jaguars and humans can be found in all the five subpopulations.
The loss of the prey base due to subsistence hunting also is a threat for jaguars in all subpopulations. In some areas the local trade market of wild species for meat use is extensive.

Conservation measures
1. This species needs effective increase in law enforcement to prevent or limit wildlife

Fig. 7. Hunted jaguar discovered in 2008 (Photo C. Campos).

hunting. Research data points to the lack of this management tool.
2. Given the need for the maintenance of the gene flow among jaguar populations, the creation of an ecological corridor including the states of Piauí, Pernambuco and Bahia is being evaluated; it would encompass an area of 2 million hectares. With the creation of this corridor the government hopes to direct conservation actions that will allow for the maintenance of jaguar populations in the biome.
3. A new national park with full protection status has been proposed and its creation covering an area of approximately 8,000 km² is in progress.

Research projects
Bahia/Piauí
Conservação da onça-pintada (Panthera onca) no Sub-Médio São Francisco: Estabelecimento do Corredor de Fauna no Nordeste Brasileiro. Coordinators: Ronaldo Morato/Rogério de Paula, CENAP/ICMBio. The goal of the project is to generate ecological information on Caatinga's jaguars and guarantee a minimum viable population through the creation and management of a Caatinga's Protected Area Network system (www.icmbio.gov.br/cenap).

Piauí
Programa de monitoramento de longa duração da população de Onças-Pintadas e suas presas naturais no PN Serra da Capivara, PN Serra das Confusões, PN Nascentes do Rio Parnaíba e ESEC Uruçuí-Una. Coordinator: Leandro Silveira–Instituto para Conservação da Onça-Pintada.

Fig. 8. Camera trap picture from the Caatinga (Photo Archive CENAP).

The goal of the project is to elaborate and start a long-term monitoring program (Fig. 8) of the jaguar population and its natural prey base (www.jaguar.org.br).

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The status of the jaguar in the Cerrado

The extent of occurence of jaguars *Panthera onca* in the Cerrado was estimated to be 157,500 km^2 and we identified 11 jaguar subpopulations in the biome by using jaguar presence points. Using data from several studies jaguar density was estimated at 0.67 mature individuals per 100 km^2 for all areas in the Brazilian Cerrado. A population of 323 adult jaguars is estimated to live throughout the biome. The Cerrado subpopulation is declining throughout the biome at an unknown rate. Jaguars have already disappeared from the areas where habitat has been converted. About half of the 2 million square kilometres of the original Cerrado were transformed into planted pastures, annual crops and other land use forms over the past 50 years. Principal jaguar threats are habitat loss, population declines, loss of prey base, jaguar killing, agribusiness, mining, roadkills and hydroelectric power.

Assessment

Endangered A2 b,c ; C2 a (i) – This subpopulation is considered Endangered due to a past reduction of more than 50% of the population in the past 3 generations (25 years) using citeria A2 b,c, and because all the subpopulations are less than 250 adult individuals (criteria C2 a(i); IUCN 2001). The subpopulation may experience some immigration from neighbouring biomes but it is expected to decrease in the next 25 years as some subpopulations may act as sinks.

Geographic range information

Extent of Occurrence EOO

The extent of occurence of jaguars in the Cerrado was estimated to be 157,500 km^2 using polygons drawn over maps of remaining Cerrado habitat (IBAMA/2009). The EOO included both the Conservation Units with known or inferred recent jaguar presence and points of jaguar presence reported by researchers, the literature and the Jaguar GIS Data compiled by the WCS "Jaguars in the new millenium" workshop. In order to calculate the EOO we included only the portions of jaguar range within Cerrado habitat (Fig. 1) while neighboring Amazon and Pantanal populations were treated separately (see other chapters of this issue).

Area of Occupancy AOO

We identified 11 jaguar subpopulations in the Cerrado biome by using jaguar presence points compiled by the Wildlife Conservation Society (Marieb 2006), Biotropicos Institute research field data and other publications (Silveira 2004, Torres 2006). These points of presence were obtained through interviews with researchers and local residents, work with camera traps, footprints, attacks on domestic animals and secondary data of the projects cited above. The area of occupancy of jaguars in the Cerrado was estimated as the sum of all occupied areas identified on the map totalling 48,000 km^2 with known or inferred recent jaguar presence (Supporting Online Material SOM Appendix I at www.catsg.org/catnews). It was presumed that jaguars use mainly good quality habitat (Fig. 2).

Ecology and population information

Population size

Using data from several studies (Silveira 2004, Astete et al. 2008, Sollmann et al. 2009, Edsel A. Moraes Jr., unpubl. data) overall jaguar density was estimated at 0.67 mature individuals/ 100 km^2 for all areas in the Brazilian Cerrado (Table 1). We opted to be conservative in all estimates. A population of 323 adult jaguars is estimated to live throughout the Brazilian Cerrado. Some jaguar subpopulations of the Cerrado may be regarded as sources or sinks.

Subpopulation 4 (Nascentes Parnaíba) indicates one of the most important populations of jaguars for the Cerrado region in the north/ northeast of Brazil. This is due to the size of the area which is well protected and because it covers two important conservation units in the National Park Nascentes do Rio Parnaíba which covers 7,350 km^2. The Cerrado transitions there into the semi-arid Caatinga biome where it is possible that this subpopulation is connected in the northern portion to the jaguar populations in the Caatinga.

Subpopulation 3 (Sertão Veredas Peruaçu) is located in an area of well preserved Cerrado in the states of Minas Gerais and Bahia. Within the area are the Conservation Units Mosaic of "Mosaico Sertão Veredas - Peruaçu", composed of 14 Conservation Units, six protected areas, two National Parks, Grande Sertão Veredas and Cavernas do Peruaçu, three State Parks (Veredas do Peruaçu, Serra das Araras and Mata Seca) and one Wildlife Refuge of Pandeiros, totaling an area of 3,465 km^2 (Funatura 2008). Although Moraes Jr (unpubl. data) has estimated a jaguar density of 2 individuals per 100 km^2 in the Grande Sertão Veredas National Park (with the presence of some melanistic individuals), the disturbed areas within the mosaic drop the

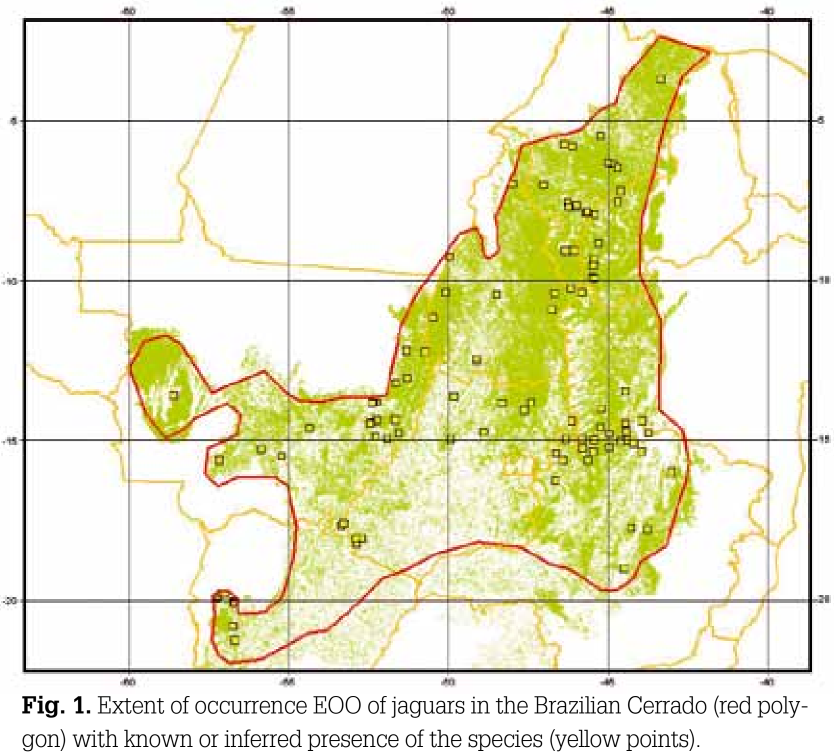

Fig. 1. Extent of occurrence EOO of jaguars in the Brazilian Cerrado (red polygon) with known or inferred presence of the species (yellow points).

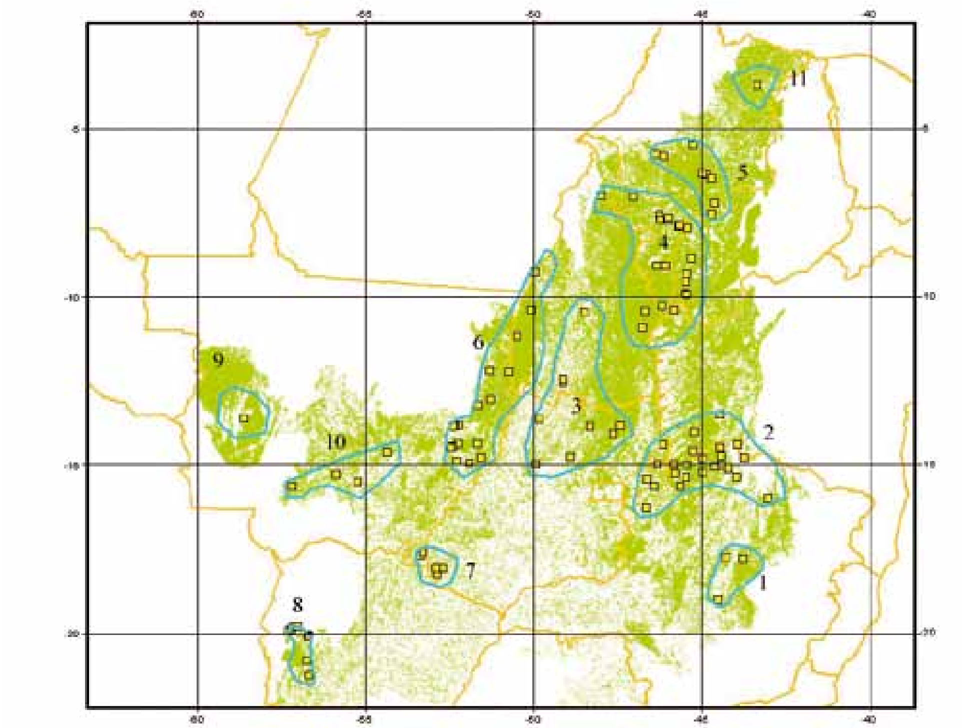

Fig. 2. Area of occupancy AOO of jaguars in the Brazilian Cerrado, inferred populations (blue polygons) with known or inferred presence of the species (yellow points) and respective numbers (Table 1).

overall density estimate to 0.67 individuals/100 km². This region is characterized by various Conservation Units protecting the Cerrado vegetation, wetlands on the river San Francisco and dry forest. It is situated very close to jaguar populations in the south Caatinga and also to the subpopulation 1 (Espinhaço de Minas Gerais), and there may be movements of animals between these populations.

The subpopulation 1 of Espinhaço in Minas Gerias, is located in the Espinhaço mountain range. Espinhaço is a priority conservation area in Brazil (Drummond et al. 2005, WWF 2001, BirdLife International 2003) and recognized as a UNESCO biosphere reserve (Candeias 2006). The Espinhaço Range divides two conservation hotspots, the Cerrado and the Atlantic Rain Forest. As a transitional area it holds high levels of species richness and presents high levels of plant endemism. Despite Espinhaço's great biological importance, its biodiversity is highly threatened: almost 70% of all plant species facing extinction in Minas Gerais state occur in this mountain range, especially in Rocky fields occurring above 1,000 meters, a typical Cerrado ecosystem. In Minas Gerais state, the Espinhaço mountain range mosaic of Conservation Units named "Mosaico do Espinhaço" will be created, "Alto Jequitinhonha – Serra do Cabral", aiming at integrated management and conservation of biodiversity in the region. Jaguar populations of northern Minas Gerais link to populations of the southern state in the Atlantic forest and therefore this region represents an important area for jaguar conservation.

Subpopulation 6 bordering the Brazilian Amazon (e.g. Araguaia region) also plays an important role for preserving jaguars. The Araguaia is Brazil's third largest river outside the Amazon basin. It originates in the Cerrado grasslands of Emas National Park and flows 1,800 kilometers to the Amazon. The 13 protected areas and five indigenous reserves along the Araguaia River strengthen its status as the most important biodiversity corridor in central Brazil. Among these protected areas are the Araguaia National Park with 1,319 km² of grassland floodplains in a transition zone between the Cerrado and the Amazon forest and the Cantão State Park. This park represents the largest block of forest along the Araguaia corridor as identified by the Jaguar Conservation Fund (Silveira 2004). Jaguars are present in the Cantão State Park and Araguaia National Park. The Araguaia gallery forest works as an important corridor for these animals (Silveira 2004).

In subpopulation 7 is the Emas National Park which encompasses 131 km² of area rich in heterogenity of the Cerrado ecosystem. Not only does it include several springs but also contains the largest grassland Conservation Unit.

Table 1. Jaguar subpopulations in the Brazilian Cerrado with the estimated area occupied by the species and number of adult jaguars in the Brazilian Cerrado. For all subpopulations we used a density of 0.67 adult jaguars/100 km². Numbers refer to polygons in Figure 2.

Number	Name	Area (km²)	Number of adult jaguars
1	Espinhaço de Minas Gerais	1,841	12
2	Sertão Veredas Peruaçu	8,418	56
3	Goiás e Tocantins	9,056	61
4	Nascentes Parnaíba	10,250	69
5	Mirador	2,981	20
6	Araguaia	7,921	53
7	Emas	1,082	7
8	Bodoquena	964	6
9	Sapezal (MT)	1,693	11
10	Chapada dos Guimarães	2,888	19
11	Norte do Maranhão	1,075	7
	Total	**48,169**	**323**

Population trends

The Cerrado subpopulation is declining throughout the biome at an unknown rate. Jaguars have already disappeared from the areas where habitat has been converted. About half of the 2 million km² of the original Cerrado were transformed into planted pastures, annual crops and other land use forms over the past 50 years (Klink & Machado 2005). Planted pastures now cover an area of 500,000 km², an area the size of Spain. Monocultures, mainly soya, cover another 100,000 km² (Klink & Machado 2005). The total area left for conservation is only about 33,000 km², clearly insufficient when compared with the main land use in the Cerrado (Klink & Machado 2005). Furthermore, Conservation Units are not large enough to maintain long-term viable jaguar populations (Silveira & Jácomo 2002). Great environmental impact such as hydroelectric dams and roads cause interruption of natural corridors used by jaguars (Silveira & Jácomo 2002), isolating subpopulations and decreasing their viability.

Subpopulations

There are at least eleven subpopulations within the biome, corresponding to the eleven polygons in Figure 2.

Threat information

Habitat loss

A recent study using satellite images from MODIS 2002 found that 55% of the Cerrado has been cleared or transformed by human action (Fig. 3; Machado et al. 2004), which is equivalent to an area of 880,000 km², or almost three times the area deforested in the Brazilian Amazon. The annual deforestation rates have also increased in the Cerrado: between 1970 and 1975 deforestation averaged 40,000 km² per year - 1.8 times the rate of Amazon deforestation during the period 1978-1988 (Klink & Moreira 2002). Current rates of deforestation vary between 22,000 and 30,000 km² per year (Machado et al. 2004), still higher than those of the Amazon.

Population declines

Population decline may be due to habitat loss, habitat degradation, loss of dispersing individuals, poaching, illegal predator control and other conflicts with humans and inbreeding. However, the rate of decline is unknown and can only be assumed. Based on known losses in some places, we think that the jaguar population in the Cerrado declined by 50% over the past 25 years.

Loss of prey base

Across much of the Cerrado biome, the potential prey base for the jaguar has been reduced due to poaching and habitat loss. In subpopulation 1 (Espinhaço de Minas Gerais) the different deer species *Mazama spp*. and white lipped peccaries *Tayassu pecari* have disappeared and collared peccaries *Pecari tajacu* are rare or absent in parts of the area. Tapirs *Tapirus terrestris*, capybaras *Hydrochoerus hydrochaeris* and giant anteaters *Myrmecophaga tridactyla* provide the main prey base to jaguars. Poaching occurs inside some Conservation Units.

Fig. 3. Agriculture and roads surrounding Grande Sertao Veredas National Park (Photo R. Araujo).

Jaguar killing

Jaguars are illegally hunted or shot throughout the Cerrado. Most of the killing is retaliation for depredation of domestic animals. Others killings are opportunistic or associated with sport hunting. In subpopulation 2 (Sertão Veredas Peruaçu) two jaguars were killed in one year (Biotrópicos Institute, unpubl. data) by poisoning or by poaching. The scarcity of jaguars in some areas of the Brazilian Cerrado may be due to persecution.

Agribusiness

The growth of agribusinesses (Fig. 4), sugar cane, cotton and particularly the soybean monocultures, makes it one of the most important threats to the Cerrado. Brazil is the second largest producer of soybeans in the world.

Mining

In the Espinhaço Mountain range the presence of large scale mining is the biggest threat to the conservation of the jaguar, causing habitat loss and degradation as well as indirect impacts such as large movement of heavy vehicles in areas surrounding Conservation Units.

Hydroelectric Power

Hydroelectric power plants cause irreversible environmental impacts. On a landscape scale the greatest impact resulting from the construction of these large reservoirs is the interruption of natural corridors for the movement of fauna which fragments populations and prevents gene flow (Carothers & Dolan 1982).

Conservation information

Conservation measures

1. Legal protection in the form of restrictive Conservation Units (CUs). More restrictive protected areas enhance jaguar conservation.
2. Effective protection of existing protected areas, performing the land regularization of the units and also in the form of intense patrolling inside the CU's. Along the regularization of protected areas went the withdrawal of all former residents of the area thus improving control and surveillance. Effective management practices in the existing protected areas: increase the number of rangers and more intense patrolling.
3. Creation of new protected areas in the biome large enough to accommodate a viable population of jaguars as well as CUs that function as corridors between populations and subpopulations.
4. Monitoring of animals for identification of ecological corridors between populations and subpopulations. Needs more research projects across the biome.
5. Implementation and maintenance of long-term research projects, thus increasing the basic data of ecology of the species in the Cerrado biome and subsidizing more conservation measures.
6. Translocations to increase depleted populations and to reduce inbreeding may be a necessity in some areas. Conducting a study to

Fig. 4. Large scale habitat distruction for the growing agrobusinesses, leaving no room for jaguar and its prey (Photo M. Ribeiro).

choose an area to carry out the translocation and implementation of a pilot project in the biome.

Research projects

1. *Grandes felinos como espécies focais para o planejamento da conservação do cerrado no Sertão dos estados de Minas Gerais e Bahia*. Localities: Parque Nacional Grande Sertão Veredas, Parque Estadual Serra das Araras, RPPN Porto Cajueiro, Refúgio de Vida Silvestre do Oeste Baiano, Parque Estadual Veredas do Peruaçu e Parque Nacional Cavernas do Peruaçu. Institution: Instituto Biotrópicos. Coordinator: Edsel Amorim Moraes Jr.

2. *Ecologia e conservação de grandes felinos do Espinhaço*. Localities: Parque Nacional das Sempre-vivas, Parque Estadual do Rio Preto, Parque Estadual do Biribiri e Parque Estadual do Pico do Itambé. Institution: Instituto Biotrópicos. Coordinator: Edsel Amorim Moraes Jr.

Parque Nacional das Emas. Institution: Instituto Onça-Pintada. Coordinator: Leandro Silveira. www.jaguar.org.br

4. *Corredor Araguaia*. Institution: Instituto Onça-Pintada. Coordinator: Leandro Silveira. www.jaguar.org.br

Parque Estadual Cantão. Institution: Instituto Onça-Pintada. Coordinator: Leandro Silveira. www.jaguar.org.br

Parque Nacional Nascente do Rio Parnaíba. Institution: Instituto Onça-Pintada. Coordinator: Leandro Silveira. www.jaguar.org.br

Estação Ecológica Uruçuí-una. Institution: Instituto Onça-Pintada. Coordinator: Leandro Silveira. www.jaguar.org.br

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The status of the jaguar in the Pantanal

The Pantanal is considered an important area for the conservation of jaguars *Panthera onca* in the long-term. In comparison to other biomes in Brazil, the Pantanal can be considered still relatively well preserved. According to a recent study, the original vegetation cover remains intact in 85% of the Pantanal plain. However, in the uplands of the Upper Paraguay watershed over 50% of the original vegetation has been altered. This situation is worrisome as this area harbors the headwaters of the rivers that are responsible for maintaining the wet and dry cycles of the Pantanal. As opposed to previously reported, only about 63% of the Pantanal biome is actually occupied by jaguars. Habitat fragmentation caused by human presence and intensification of land use is a threat to jaguars in the Pantanal. Other threats include high levels of retaliation from ranchers due to livestock depredation and the lack of enforcement by wildlife authorities, illegal hunting tourism activity, pasture management through the use of annual fires, and the mining industry. The first estimate of a jaguar population in Brazil was conducted in the southern Pantanal (6.5-7.0 jaguars/km²), although the distribution of the species is heterogeneous, which precludes an accurate estimation of the current population size in this biome. Authorities should recognize the cost associated with grazing cattle in an area where jaguars exist in considerable numbers and regularly prey on cattle. A unique regional policy could address some of the problem, perhaps in the form of tax benefits, special lines of credit, or a regional increase in beef prices. It is important that environmental actions be implemented to increase market value of cattle raised in the region without changing the main characteristics of the Pantanal.

Assessment

Near Threatened – Due to loss of habitat, increased human presence and intensification of land use, as well as poaching of jaguars, this species is considered to be Near Threatened in the Pantanal biome.

Geographic range information

Extent of Occurrence EOO and Area of Occupancy AOO

The Brazilian Pantanal biome encompasses about 140,000 km^2. Results from the range-wide assessment developed by the Wildlife Conservation Society (WCS) in 1999 suggest that 91-100 % of the biome is occupied by jaguars (Sanderson et al. 2002, Marieb 2005). Their extent of occurrence encompasses about 125,000 km^2 (S. Cavalcanti, map adapted from a MMA Pantanal map and results from the Pantanal Landscape Species Workshop, organized by WCS in Corumbá, 2003).
An exercise by Brazilian researchers working in the Pantanal (Pantanal Landscape Species Workshop, 2003) suggests that only about 63 % or 88,200 km^2 of the Pantanal biome is actually occupied by jaguars (Fig. 1). The area of occupancy exclude most of the Taquari Alluvial Fan, parts of the Cáceres sub-region, portions of the Nabileque sub-region (south of Corumbá), and areas in the north-eastern and eastern border of the Pantanal.

Fragmentation

In general, and in comparison to other biomes in Brazil, the Pantanal can be considered still relatively well preserved (Fig. 2). The inaccessibility of much of its area restricts agricultural practices and deforestation on the plains (Fig. 3). Beef cattle ranching on the savannas with flooding native pastures is relatively less destructive of the environment than large scale agricultural fields.
Less than 20 years ago, the deforestation in the Pantanal was quantified as 5,438 km^2 or 3.9% of the Pantanal area (Silva et al. 1992). In 1993 Mourão et al. (2000) observed that much of the upland areas originally covered by forests or savanna woodlands had been cleared and replaced by pastures. Deforestation areas corresponded to 9,490 km^2 or 6.8% of the Pantanal. In 2000 Padovani et al. (2004) quantified the deforested area as 12,182 km^2 or almost 9% of the total Pantanal area.
According to Mourão et al. (2000), deforestation for pastures has started to spread from the east to the Taquari Alluvial Fan (Nhecolândia and Paiaguás sub regions) and along the courses of the Aquidauana and Miranda rivers. The spread of man-made pastures has been especially intense in the Cáceres sub region (area of Corixo Grande) and in the Taquari river watershed, mainly near the city of Coxim.
The most current information on the status of the vegetation cover in the Pantanal reveals that in the last 9 years (2001-2009) deforestation has accounted for an additional 6% of the area of the Pantanal. The data derives from a recent ongoing survey initiated in the middle of 2008 and carried out by 5 Non-Governmental Organizations (WWF-Brazil, SOS Mata Atlântica, Conservation International, Avina, and Ecoa) with the support of researchers from EMBRAPA Pantanal. According to the study the original vegetation cover remains intact in 85% of the Pantanal plain. However, in the uplands of the Upper Paraguay watershed over 50% of the original vegetation has been altered. This situation is worrisome as this area, adjacent to the plain, harbors the headwaters of the rivers that are responsible for maintaining the wet and dry cycles of the Pantanal (Harris et al. 2005).
In addition to deforestation and fires, human presence causes habitat fragmentation. Over the past several decades, ranches in the Pantanal have decreased in size as land has been subdivided among family members. This division has increased access to areas that were formerly remote and had little movement of vehicles and people. This trend is likely to continue, or even intensify, thereby increas-

Fig. 1. Extent of Occurrence EOO and Area of Occupancy AOO for the jaguar in the Brazilian Pantanal.

Fig. 2. Aerial photograph of a ranch in the northern Pantanal, in the district of Poconé, Mato Grosso, Brazil (Photo S. Cavalcanti).

ing access to prime jaguar habitat. This fragmentation of land decreases its profitability; to maintain economically viable operations, many ranchers opt to increase herd size. This intensification in grazing pressure increases the need for open pastures and introduced grasses which further modifies native habitats.

Ecology and population information

Population size

The few formal attempts to describe jaguar occurrence in the Pantanal have indicated that the jaguar has a heterogeneous distribution in the region (Quigley & Crawshaw 1992). The lack of information for most of the different subtypes of the Pantanal precludes an accurate estimation of the current population size in this biome. It is believed however that the Pantanal still holds a large population of jaguars (Soisalo & Cavalcanti 2006).

In one of the pioneering studies of jaguars in the late 1970's, Crawshaw & Quigley (1991) estimated a population of 3.2 jaguars/100 km^2 in the southern Pantanal. The authors noted however, their data was only speculative. More recently Soisalo & Cavalcanti (2006) published the first estimate of a jaguar population in Brazil based on camera-trap data in conjunction with GPS radio-telemetry data. Their data indicate that in the southern Pantanal, jaguars occur at a density of 6.5-6.7 jaguars/100 km^2. These results are consistent with the estimate of 7.0 jaguars/100 km^2 Azevedo & Murray (2007) reported for the same general area.

Fig. 3. Aerial image of a ranch in the southern Pantanal during the wet season, showing the area's inaccessibility (Photo S. Cavalcanti).

Population trends

Over the past several years there has been increased speculation on the numbers of jaguars in the Pantanal. Ranch owners and cowboys claim that jaguar numbers have increased (Marchini 2003). The suggestion that jaguar numbers are increasing is controversial among government officials, environmentalists and livestock producers throughout the country. There is little evidence whether the presumed increase in jaguar/livestock conflicts are related to increased numbers of these carnivores, increased number of cattle, increased contact due to habitat fragmentation, or increased attention from the media.

Until recently this controversy could not be evaluated due to a lack of baseline data on population numbers. Information on jaguar populations in the Pantanal have been published in the last few years (Soisalo & Cavalcanti 2006, Azevedo & Murray 2007). Although the data from these two studies are consistent at 6.5-7.0 jaguars/100 km^2, it would be unreasonable to assume a stable trend as the studies cover a short period of time. In order to evaluate the trend of the jaguar population in the Pantanal additional estimates from subsequent time periods are needed.

Subpopulations

Within the Pantanal there are no significant barriers that could potentially hinder jaguar dispersal. However, there are regions that are significantly affected by factors such as human presence, density of roads and towns, etc. These areas may hamper jaguar movement to a degree, although it is unclear whether they would separate individuals into subpopulations. Jaguars could possibly be divided into 2 subpopulations (Fig. 4) which would be reasonably connected by the lowland corridor along the Paraguay River. The southern population would be separated from the northern population by the area to the southeast of Corumbá near Fazenda Bodoquena and its surroundings, which has been severely deforested, but probably does not keep jaguars from moving between the two areas.

Extreme fluctuations

Given the diversity of prey species characteristic of the Pantanal and the ability of jaguars to readily switch prey (Cavalcanti & Gese

2010), it is unlikely that jaguar populations undergo severe fluctuations in the biome. Nevertheless, this statement may depend on the time scale being considered. In the late 1970's, jaguars were almost extinct over most of the Pantanal (Schaller 1979) and presently they appear to exist in considerable numbers (Soisalo & Cavalcanti 2006, Azevedo & Murray 2007).

Other life history information

Jaguars are challenging to study. Nevertheless, our knowledge on jaguars has increased since the first field studies in the mid 1980's as several studies have helped uncover different aspects of their ecology and life history (Crawshaw et al. 2004, Novack et al. 2005, Polisar et al. 2003, Scognamillo et al. 2003, Cullen et al. 2005, Palmeira et al. 2008, Harmsen et al. 2009).

The reproductive profiles of female jaguars indicate a lack of an established mating season, i.e., asynchrony, suggesting they associate with males throughout the year (Cavalcanti & Gese 2009). The breeding pattern suggests successful mating taking place at roughly two-year intervals and offspring becoming independent at an approximate age of 18-24 months. Male offspring tend to disperse further than females (Quigley & Crawshaw 2002), thus being the key element in colonizing new areas and in linking subpopulations with dispersal movements.

Cavalcanti & Gese (2009) suggest that the mating system in jaguars may be one of a polygynous and promiscuous nature; a male likely mates with several females and a female mates with several males.

Soisalo & Cavalcanti (2006) found a male: female ratio of 1.5:1 and 1.2:1 during 2003 and 2004, respectively. In a different study area, Azevedo & Murray (2007) reported a male:female ratio of 0.6:1. This might represent different methodological approaches adopted by the two studies or the presence of transient males on the former studied population.

Although there is still a lack of consistent information on jaguar dispersal, jaguars have been reported to disperse over 60 km in the Atlantic Forest (Iguaçu National Park, Crawshaw et al. 2004) and 30 km in the Pantanal (Quigley & Crawshaw 2002, S. Cavalcanti, unpubl. data).

The locations of female jaguars suggest a pattern of spatial avoidance among females during the wet season. Home range overlap among males is extensive both in the wet and in the dry seasons, suggesting that males do not maintain exclusive ranges. Overlap between males and females occurred both in the wet and dry seasons (Cavalcanti & Gese 2009).

Threats

One of the main threats to jaguars in the biome comes from high levels of retaliation from ranchers due to livestock depredation. Historically, jaguars have been killed in the Pantanal as a way to curtail livestock depredation by the large cats (Crawshaw & Quigley 1991, Lourival & Fonseca 1997) even though the amount of damage incurred by jaguars may be less significant than that incurred by other sources of mortality (such as droughts, malnutrition and diseases; Hoogesteijn et al. 1993).

Jaguar persecution goes beyond the economic aspect as it has also a cultural aspect (Cavalcanti et al. 2010). Jaguar hunts are viewed as an act of bravery and dexterity among cowboys, a way to increase their personal status within the community (Banducci Jr. 2007), and therefore remains a common practice in the Pantanal (B. Rondom, pers. comm., V. Correia, pers. comm).

Another serious threat comes from the lucrative illegal hunting tourism activity involving national and international hunters (Almeida 1990, Azevedo & Murray 2007, B. Fiori, pers. comm.).

Although jaguars are fully protected at the national level across most of its range (IUCN 2009), cultural traditions in the Pantanal coupled with the characteristics of the area and the lack of enforcement by wildlife authorities contribute to the regular illegal shooting of these cats. The illegal nature of this hunting makes it difficult to quantify and monitor its effect on the population. The shooting of jaguars remains a regular activity even in areas where landowners have banned the practice.

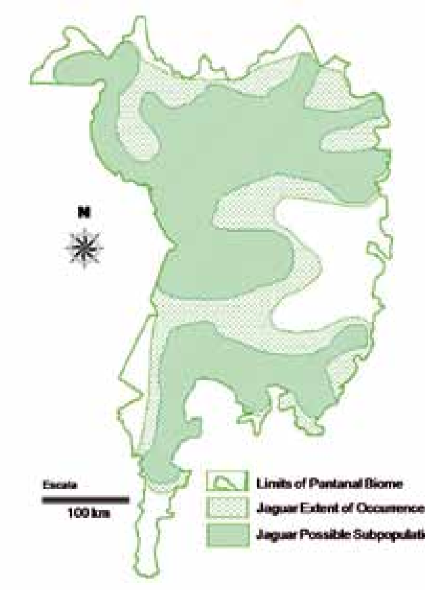

Fig. 4. Possible jaguar subpopulations within the Pantanal biome.

Increasing deforestation for the implementation of pastures of native and exotic grasses for grazing cattle is another threat that likely disrupts jaguar movements and habitat use (Fig. 5). As previously mentioned, deforestation is more severe in the southeast and north-west borders of the plain.

Pasture management through the use of annual fires, although controversial, also im-

Fig. 5. Area in the southern Pantanal formerly covered by native trees deforested for the implementation of pastures for cattle grazing (Photo W. Tomas).

Fig. 6. Pasture management through the use of annual fires in the Pantanal (Photo S. Cavalcanti).

pacts important natural habitats and kills several prey species. It also probably changes jaguar density in some areas, by disrupting their movements and habitat use. These effects may be especially severe in dry years, when shrubs and trees are less resistant to fire (Fig. 6).

Charcoal production is a potential indirect threat for jaguars in that it may generate incentives for additional deforestation. Wood for charcoal production is usually obtained from sites that have been legally deforested for pasture implementation (Fig. 7). In that sense, it is a legal activity. However, given that wood selling for charcoal production enhances the economic viability of pasture implementation, it tends to be an incentive for the creation of additional pastures and consequent deforestation.

The mining industry is considered a great threat to the Pantanal environment and indirectly to jaguars, both in the north, where there is gold and diamond extraction, and in the south, where there is iron, manganese and limestone extraction (Fig. 8). The district of Poconé has presently fourteen large gold mines and two-hundred smaller excavation sites (PM Pocone 2010). This recent gold mining activity has created great environmental problems, including water and soil contamination with mercury, river sedimentation and changes in the banks of rivers and lakes.

Fig. 7. Furnaces for charcoal production installed in Pantanal ranches on areas that have been recently deforested. Not only they make pasture implementation economically more viable, but also help with the "cleaning" of recently cut areas (Photo W. Tomas).

Locations

The persecution of jaguars by ranch employees occurs throughout the Pantanal biome. It affects both male and female jaguars in all age classes as it is done both opportunistically and in a preventive manner, even before depredations occur. The practice of sport hunting is more localized, but because of its illegal nature, it is difficult to determine precisely where it happens and how much impact it poses to jaguars.

Increasing deforestation is most intensive near the borders of the Pantanal plain, but it happens throughout the biome as well. Considering the ongoing survey carried out by WWF-Brazil, SOS Mata Atlântica, Conservation International, Avina, and Ecoa, the current rate of deforestation in the Pantanal is about 0.67%/year or 6% over the last 9 years. Considering the total area of 140,000 km^2, the annual area being deforested in the plain is about 938 km^2/year, which is quite significant. Considering the non-overlapping home ranges of female jaguars, the total area deforested every year is almost the size of the area occupied by 20 jaguars. But this figure is likely an underestimate given that not all the 140,000 km^2 of the plain is covered by forests.

Another significant threat, the use of annual fires for management of pastures, happens throughout the biome and during drier years may affect even the lower areas of the Pantanal, where most of the jaguars are found. Charcoal production as a threat in the form of incentive for additional pasture implementation is particularly serious in the Miranda/ Aquidauana regions, near the southern border of the plain.

Conservation measures

Authorities should recognize the cost associated with grazing cattle in an area where jaguars exist in considerable numbers (Soisalo & Cavalcanti 2006) and regularly prey on cattle. An unique regional policy could address some of the problem, perhaps in the form of tax benefits, special lines of credit, or a regional increase in beef prices. It is important that environmental actions be implemented to increase market value of cattle raised in the region without changing the main characteristics of the Pantanal. Certain actions have already been tested or put into place, such as organic certified cattle ranching. With the objective of making business ventures economically viable while maintaining the region's environmental and social balance, local ranchers have participated in the organic certified cattle ranching (ABPO Organic Pantanal, http://assets.wwfbr.panda.org/downloads/organic pantanal.pdf, January 2010). Although the international protocols of meat production do not include actions for wildlife conservation, ABPO follows an internal protocol that establishes some environmental directives important from a conservation standpoint.

Embrapa Pantanal has been conducting a 7-year project with the main objective of establishing sustainability criteria/indicators that are specific for Pantanal ranches and include environmental issues. The focal point of the different criteria for ranch evaluation and decision making is biodiversity conservation. This could result in a certification or a stamp of approval program. The adoption of low impact production systems together with an added value to Pantanal meat products can be beneficial for jaguar conservation. This added value via a possible certification program could compensate, throughout the market system, the economic losses caused by jaguar depredation and the lower profitability from lower impact production systems. Embrapa Pantanal has been taking the necessary steps to increase the value of low impact systems, working with ABPO in the search for a strategy that could join both initiatives (organic cattle and sustainability). The institution also works toward a system that is applicable to other production systems, such as the traditional Pantanal ranches that are not part of the organic meat initiative.

Traditional ranchers should focus on increasing their production potential, curtailing losses due to rudimentary herd management and poor husbandry practices, which can be more significant than jaguar depredation (Hoogesteijn et al. 1993). Although predation on cattle in the Pantanal will likely always occur, the results from recent studies (Azevedo & Murray 2007, Cavalcanti & Gese 2010) illustrate the importance of maintaining native prey populations as a possible means of minimizing these conflicts.

The establishment of private reserves inside ranches is another important measure towards conservation of jaguars in the Pantanal. Private reserves act as a guarantee of maintenance of the original natural landscape without human modification. Benefiting from local and federal governments, local ranchers have converted part of their lands into private reserves, or RPPNs. Currently, more than 2,100 km^2 of land are set aside as private reserves in the Pantanal (Harris et al. 2005) and this figure is likely to increase. The recent purchase of large tracts of land by owners that are committed to conservation in the northern Pantanal has produced a mosaic of private ranches interspersed with state and federal parks to create an almost continuous corridor that adds up to roughly 300,000 km^2 encompassing the areas of SESC Pantanal, Mata do Bebe, Encontro das Águas and Guirá State Parks, Pantanal National Park, São Bento, Porto Jofre and Baía Vermelha Ranches, RPPNs Penha, Acurizal, Dorochê, Rumo a Oeste, and Novos Dourados. Such initiatives in strategic locations would definitely contribute to reduce the decline in jaguar distribution or population size.

Fig. 8. Gold mining near the municipality of Poconé, in the state of Mato Grosso, Brazil (Photo R. Boulhosa).

Long-term ecological studies are also vital for the conservation of jaguars in the Pantanal. Some recent long-term studies have provided important information on jaguar's spatial organization, food habits, density estimates, genetics and predation impact on livestock in the Pantanal (Soisalo & Cavalcanti 2006, Azevedo & Murray 2007a, 2007b, Eizirik et al. 2008, Cavalcanti & Gese 2009, 2010). However, there is a lack of studies on demographic parameters such as age at first reproduction, litter size, age at dispersal, dispersal distances, population sizes, etc, human/predator conflicts and jaguar prey base availability which precludes implementation of management actions. This type of information can contribute to better management decisions that not only minimize cattle depredation by jaguars but that also contribute to increasing acceptance of jaguars by ranchers.

Current research projects

1. *Jaguar Ecology in the Pantanal – The Northern Corridor*. Coordinator: Peter G. Crawshaw Jr. and Panthera. The objectives of the project include the foraging, spatial, and social ecology of jaguars, as well as examining demographic parameters of the studied population.
2. Indicators of Sustainability. Coordinator: Embrapa Pantanal – CPAP. This program encompasses 4 or 5 integrated projects, that have been developed since 2002 to implement a ranch evaluation/certification system for the Pantanal.

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Population Viability Analysis of jaguar populations in Brazil

Population viability analysis (PVA) was used during the workshop for the Jaguar National Action Plan to better understand jaguar population dynamics and simulate different scenarios to understand the impact of threats and projected outcome of potential conservation strategies. The method is explicitly designed to broaden stakeholder involvement and enhance information sharing across disparate scientific and social domains. During the Jaguar National Action Plan workshop a base model was built for jaguars, a sensitivity analysis was run, and theoretical case studies of questions and situations raised by the participants were developed. The focus of this work was to examine concepts of jaguar population dynamics, stimulate discussions on jaguar life history parameters, fuel discussion on different threats, evaluate potential impact of these threats, and introduce participants to concepts of population viability analysis and its value as conservation planning tool.

Small populations of animals are at risk of extinction not only due to threats such as habitat loss and poaching, but are also particularly vulnerable to the impacts of stochastic (chance) processes that can lead to extinction. During the Jaguar National Action Plan workshop the simulation software program Vortex (v9.96) was used to examine the viability of jaguar populations. Vortex simulates the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild or managed populations, making it well suited to assess the viability of small populations. Vortex models population dynamics as discrete sequential events that occur according to defined probabilities. The program begins by creating individuals to form the starting population and then steps through life history events (e.g., births, deaths, dispersal, catastrophic events), typically on an annual basis. Population attributes such as breeding success, litter size, sex ratio at birth, and survival rates are determined based upon designated probabilities that are established during the workshop based on the literature and participant expert knowledge. Specific events that occur in the lifetime of an individual are uncertain, so probabilities are used to determine what happens to each animal in each simulated future. Consequently, each run (iteration) of the model gives a different result. By running the model hundreds of times, it is possible to examine the probable outcome and range of possibilities for the future of a population.

For a more detailed explanation of Vortex and its use in population viability analysis, see Lacy (1993, 2000) and Miller & Lacy (2005).

Population viability analysis (PVA) enables workshop participants to better understand jaguar population dynamics and simulate different scenarios to understand the impact of threats and projected outcome of potential conservation strategies. The method is explicitly designed to broaden stakeholder involvement and enhance information sharing across disparate scientific and social domains. Each participant is encouraged to add his or her knowledge of the species and its situation, potential actions, and additional questions to develop scenarios to be examined through modeling.

During the Jaguar National Action Plan workshop a base model was built for jaguars, a sensitivity analysis was run, and theoretical case studies of questions and situations raised by the participants were developed. The focus of this work was to examine concepts of jaguar population dynamics, stimulate discussions on jaguar life history parameters, fuel discussion on different threats, evaluate potential impact of these threats, and introduce participants to concepts of population viability analysis and its value as conservation planning tool. During the workshop the viability of jaguar populations from the different biomes was NOT examined, but will be investigated in the near future based on this initial work and the maps developed during the workshop (Ferraz et al. 2012, this issue).

Base model

Due to the potential variation of several parameters among the different biomes it was decided to construct a general base model for jaguars that could then be tailored to specific Brazilian biomes and specific jaguar populations. The base population model was designed to investigate the viability of a non-specific but biologically accurate jaguar population. Details of the parameters used in the base model are available in Table 1.

Some parameters were debated at length by workshop participants. For example some participants felt that females could have their first litter at 2 years of age and males at 3, while others insisted females on average would have their first litter at 3 years of age, as they need to have an established territory and be in good physical condition. There was also considerable debate about whether jaguar reproduction is density dependent. At high densities some participants thought that animals will compete for prey, territories and mates, limiting reproduction. However, others felt that in solitary living carnivores reproduction is not necessarily density dependent. A value of the PVA modeling approach is that it helps to identify such different perspectives, and then allows sensitivity testing of the effects of alternative values without prejudging which is closer to the truth.

After some discussion, maximum age was set at 15 years; however mortality rates after 10 years were increased in the model so that very few individuals (~5%) actually reach such an old age. By comparing observed population growth rates to those calculated for different plausible values of age-specific mortality, the workshop participants were able to come to consensus around the best estimates of mortality to use in the models. Mortality rates were set highest for the first year of life, moderate during years when cubs are with the mother or dispersing, and lowest for prime age adults, with increasing mortality after 10 years of age.

The base model represents the biological potential of jaguars: no harvest, no increase in mortality due to road kill, disease or fire, and no catastrophes are included. This does not represent a realistic situation, but provides the basis upon which future models that include these and others threats can be constructed.

The demographic rates (reproduction and mortality) included in the base model can be used to calculate deterministic characteristics of the model population. These values

Table 1. Summary of parameter input values used in the base model; EV = environmental variation, expressed as a standard deviation. Details for these values are given in the action plan (de Paula et al. 2010).

Parameter	Base value
Breeding system	Polygyny
Age of first reproduction (λ/ λ) in years	3 / 4
Maximum age (in years)	15
% adult males in breeding pool	90
Density dependent reproduction?	debated
Annual % adult females reproducing (EV)	50 (5)
Average litter size	2
Maximum litter size	4
Overall offspring sex ratio	50:50
% mortality from age 0-1 (EV) (λ/ λ)	42(7)/ 42(7)
% mortality from age 1-2 (EV) (λ/ λ)	17(3.5)/ 17(3.5)
% mortality from age 2-3 (EV) (λ/ λ)	20(5)/ 20 (5)
% mortality from age 3-4 (EV) (λ/ λ)	6(1.5)/ 25 (6)
% mortality from age 4-10 (EV) (λ/ λ)	8(1.5) / 10(2)
% mortality from age 10-15 (EV) (λ/ λ)	Add'l 5 % mort. ea. yr.
Inbreeding depression	6 lethal equivalents
% of inbreeding effect due to recessive lethal alleles	50

are a good initial summary of the population characteristics, as they reflect the biology of the population in the absence of stochastic fluctuations (both demographic and environmental variation), inbreeding depression, limitation of mates, and immigration/emigration. The base model results in a deterministic growth rate for females of (rdet) of 0.060 (λ= 1.058). This represents an annual potential growth rate of almost 6%. Adult sex ratio is female biased and the sex ratio of adult males to adult females is 1:2.7. Adult individuals (sexually mature individuals) represent 51% of the population (SOM Table 2 at www.catsg.org/catnews).

Results from the base model (500 iterations) project that a population of 200 jaguars in the absence of threats is likely to persist over the next 100 years. When N=100 and K=200 the stochastic growth rate (r-stoc, the mean rate in the simulated populations, subjected to all the demographic, genetic, and environmental uncertainty in the model) is 0.027, representing an annual population growth of almost 3%, enabling the population to grow when below carrying capacity. There is zero probability of extinction (PE) in 100 years, and the mean population size at 100 years is 187 jaguars with 91.28% gene diversity remaining (Supporting Online Material SOM Fig. 1).

Sensitivity analysis of demographic rates

Sensitivity analysis is a tool used to evaluate the robustness of a model to variations in parameter values. The most sensitive parameters require greater certainty in the input values to produce more confident results. This also helps to identify where further research is needed. Sensitivity analyses using highest and lowest values for each demographic rate were compared to evaluate the effect of model parameters on the stochastic growth rate (r-stoc) of jaguar populations. Mortality rates were increased and decreased by 25%, 1 year was either added or subtracted to age of first reproduction, 4 years were added/subtracted to maximum age of reproduction, and average litter size was increased or decreased by 25%. Results from the sensitivity analysis indicate that reproductive parameters and female mortality rates are the most sensitive parameters across the values tested, while male demographic values are less sensitive (Supporting Online Material SOM Fig. 2). This is logical for a polygynous species, in which females represent the breeding potential and therefore the ability of the population to grow and recover from declines.

Theoretical case studies

Importance of population size

To illustrate the importance of population size in jaguar populations, a modeling exercise was run during the workshop in which the initial population (N) was varied as well as the carrying capacity (K) when K>N and when K=N. Many different values were tested, ranging from 15 to 200. This exercise demonstrated that population size (both in terms of N and K) is a very important factor in determining the population growth, long-term persistence and genetic diversity of jaguar populations (SOM Tables 3 and 4). Small isolated populations of jaguars cannot persist in the long term. However, a high carrying capacity may decrease the impact of small population size on population growth, long-term persistence, genetic diversity and mean time to extinction, as it may allow the population to grow to a larger size, and once it is larger, it is less vulnerable. Therefore for conservation purposes, protection and maintenance of habitat quantity and quality (cover and prey base), which determines carrying capacity, are imperative for the long-term conservation of jaguars.

Impact of harvest of adult females

Killing of adult jaguars through sport hunting, traditional hunting or retaliation for economic loss all have the same result: loss of adult individuals (breeders) from the population. The sensitivity analysis showed that an increase in mortality of females negatively impacts jaguar populations. For the purpose of this exercise we modeled removal of adult female jaguars. Results show that the smaller the initial population, the higher the impact harvesting of female jaguars will be (Fig. 1). Smaller populations have higher probabilities of extinction and lower growth rates. In practical terms this means that removal of female jaguars from small isolated fragmented populations will have a much bigger impact on the population viability than removal of the same number of individuals from a larger population. Overall jaguars cannot sustain high levels of harvest given a theoretical maximum growth rate of only about 5%. Even if the initial population size is high, jaguar population growth rates will decline when harvest increases, and may ultimately drive populations to extinction.

Impact of fragmentation

Habitat loss, fragmentation and isolation of jaguar populations were repeatedly mentioned as one of the main threats to long-term persistence of jaguar populations in Brazil. Amongst its many impacts, habitat fragmentation reduces population size and smaller populations are more vulnerable to stochastic processes (including inbreeding) and have a higher risk of extinction. Corridors that link fragmented habitats are often advanced as a potential solution. During the workshop models were created to test the impact of corridors. Models suggested that corridors can either prevent or cause the extinction of jaguar populations, depending upon the situation. Metapopulation dynamics are complex and many factors come into play such as size of fragments, dispersal rate, demographic rates in the various fragments, and the survival and reproductive rates of dispersing animals (SOM Figure 4). Corridors to poor-quality or unprotected habitat ("sinks") or to areas too small to harbor a healthy breeding population can further de-stabilise the overall population. Further exploration and caution should be used when considering corridors as a conservation measure.

Translocations and re-introductions

During the workshop jaguar translocations and re-introductions were discussed. Due to logistical difficulties, potential risks and high cost, there is a lot of controversy surrounding this conservation option. As an exercise during the workshop we tested some re-introduction/translocation scenarios (SOM Table 5). The modeling showed that there are many aspects to be explored in order to guide and formulate a re-introduction program, such as age, sex, number of animals, reintroduction interval, re-introduction time period, survival and fecundity rates of reintroduced animals, and many more. The modeling exercise showed that re-introductions need to be well planned and part of a comprehensive program to be effective tools for conservation of jaguar populations.

Real case studies

During the workshop we also investigated several real case studies. The impact of hunting on a jaguar population from the Tapajós-Arapiuns Extractive Reserve, Central Amazonia was investigated using data collected by Elildo A. R. Carvalho Jr. (ICMBIO Parna Grande Sertão Veredas). Modeling was first used to evaluate the importance of some of the data gathered during the field study. For example, the model showed that data on the sex of animal hunted had a significant impact on the final outcome of the model, while knowledge of the age class of jaguars hunted (adults or sub-adults) had less impact. Modeling was then used to predict the impact of hunting and source-sink dynamics between the reserve and surrounding areas. The viability of the Minas Gerais Espinhaço jaguar population in the Cerrado was investigated, and a wide array of conservation measures to protect the population was tested using data collected by Edsel Amorim Moraes Jr and Rafael Luiz Aarão Freitas (Instituto Biotropicos). Tadeu Gomes de Oliveira (UEMA & Pro-Carnivoros) modeled the importance and impact of protecting the Nascentes Parnaíba Jaguar population in the Cerrado. The long-term viability of jaguar populations from each biome is currently being investigated and will be used to make specific conservation recommendations for each biome.

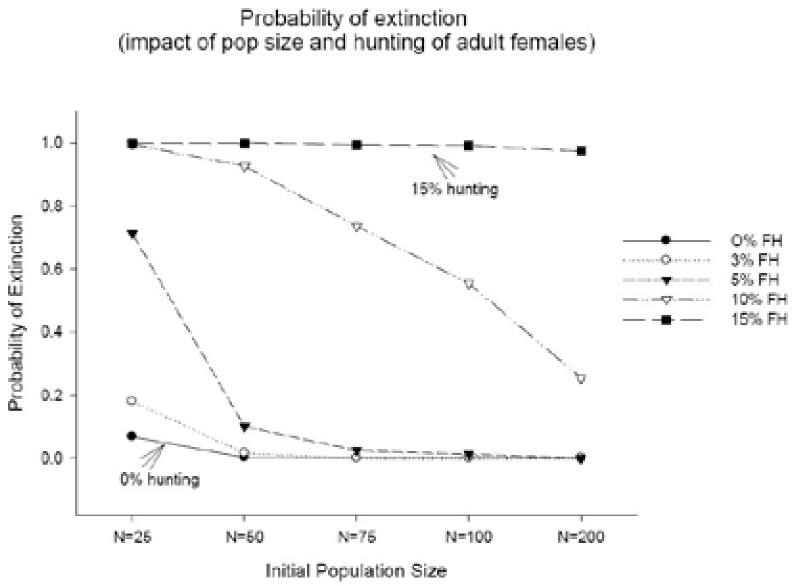

Fig. 1. Probability of extinction (within 100 years) of jaguar populations in relation to initial population size and percent harvest (H) of adult female jaguars.

Conclusion

Using computer models such as Vortex during a workshop helps to integrate detailed data on species biology, genetics, and ecology with estimates of human-based threats to evaluate the risk of wildlife population decline or extinction under alternative future management scenarios. One of the advantages of using Vortex in a workshop is that it is a participatory exercise that helps participants understand long-term impacts, threats and probable trajectories of animal populations. It also helps experts determine the state of knowledge on the species and pinpoint areas where future research is needed. It helps to extract important data and knowledge from all participants and advance knowledge of the species. A model cannot make value decisions about what to conserve and why, nor can it guarantee that the needed actions will be implemented, but modeling does empower participants by giving them a scientifically sound method to integrate their knowledge into a comprehensive picture of population dynamics, risk analysis, and assessment of options. Thus, it can serve as an excellent tool for scientists and wildlife managers to work together in their quest to make better decisions about conservation.

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How species distribution models can improve cat conservation - jaguars in Brazil

Modeling species distribution is a promising field of research for improving conservation efforts and setting priorities. The aim of this study was to produce an environmental suitability map for jaguar distribution in two biomes in Brazil – Caatinga and Atlantic Forest – , where the species is Critically Endangered as part of the Jaguar National Action Plan workshop (Atibaia, São Paulo state). Species occurrence (N = 57 for Caatinga and N = 118 for Atlantic Forest), provided by jaguar specialists, and ten environmental predictors (elevation, land cover, distance from water and bioclimatic variables) were used to generate species distribution models in Maxent. Both models presented high predictive success (AUC = 0.880 ± 0.027 for Caatinga and AUC = 0.944 ± 0.022 for Atlantic Forest) and were highly significant (p < 0.001), predicting only 18.64% of Caatinga and 10.32% of Atlantic Forest as suitable for jaguar occurrence. The species distribution models revealed the low environmental suitability of both biomes for jaguar occurrence, emphasizing the urgency of setting conservation priorities and strategies to improve jaguar conservation such as the implementation of new protected areas and corridors for species dispersal.

Predicting species distribution has made enormous progress during the past decade. A wide variety of modeling techniques (see Guisan & Thuiller 2005) have been intensively explored aiming to improve the comprehension of species-environment relationships (Peterson 2001). The species distribution modeling (SDM) relates species distribution data to information on the environmental and/or spatial characteristics of those locations. Combinations of environmental variables most closely associated to presence points can then be identified and projected onto landscapes to identify areas of predicted presence on the map (Soberón & Peterson 2005, Elith & Leathwick 2009). The geographic projection of these conditions (i.e., where both abiotic and biotic requirements are fulfilled) represents the potential distribution of the species. Finally, those areas where the potential distribution is accessible to the species are likely to approximate the actual distribution of it.

The jaguar, the largest felid in the Americas, has been heavily affected by retaliation killing for livestock predation, fear, skin trade, prey depletion, trophy hunting (e.g. Smith 1976, Conforti & Azevedo 2003) and habitat loss (Sanderson et al. 2002). As a consequence, it is now restricted to ca. 46% of its former range (Sanderson et al. 2002).

Environmental suitability models have been produced for jaguar distribution in Brazil during the Jaguar National Action Plan Workshop, facilitated by IUCN/SSC CBSG Brazil and organized and funded by CENAP/ICMBio, Pró Carnívoros and Panthera, in November 2009, Atibaia, São Paulo state, Brazil. During the workshop, jaguar specialists provided occurrence point data for species distribution modeling. A jaguar database was composed only by recent (less than five years) and confirmed records (e.g., signs, telemetry, camera-trapping, chance observations). All models and detailed information about the procedure and the results are included in the Jaguar National Action Plan. Background information on SDM and necessary considerations are summarized in the Supporting Online Material Appendix I (www.catsg.org/catnews). Here, to illustrate the potential of the use of the SDM for cat conservation, we presented the environmental suitability models for jaguar in two biomes (Caatinga and Atlantic Forest, Fig. 1), where the species is considered Critically Endangered in Brazil (de Paula et al. 2012, this issue; Beisiegel et al. 2012, this issue).

Table 1. Environmental predictor variables used in jaguar distribution model.

Variables	Description
Land cover	Land cover map from GlobCover Land Cover version V2.3, 2009
Elevation	Elevation map by NASA Shuttle Radar Topography Mission
Distance from water	Map of gradient distance from water obtained from vector map of rivers from IBGE
Bioclimatic variables	Maps of bioclimatic variables from Worldclim:
	Bio1 = Annual mean temperature
	Bio2 = Mean diurnal range (mean of monthly (max temp - min temp))
	Bio5 = Max temperature of warmest month
	Bio6 = Min temperature of coldest month
	Bio12 = Annual precipitation
	Bio13 = Precipitation of wettest month
	Bio14 = Precipitation of driest month

Methods

Jaguar distribution was modeled for each biome separately considering the differences between the environmental spaces (i.e., conceptual space defined by the environmental variables to which the species responds). The biome map used was obtained from a Land Cover Map of Brazil (1:5.000.000), 2004, by the Brazilian Institute of Geography and Statistics, IBGE (available for download at http://www.ibge.gov.br/).

Predictive distribution models were formulated considering the entire available jaguar dataset as the dependent variable (presence points) and the selected environmental variables as the predictors (Table 1). Jaguar data available for modeling (N = 57 for Caatinga; N = 118 for Atlantic Forest; Fig. 2) were plotted as lat/long coordinates on environmental maps with a grid cell size of 0.0083 decimal degree^2 (~1 km^2).

Models were obtained by Maxent 3.3.3e (Phillips & Dudík 2008) using 70% of the data for training (N = 40 for Caatinga and N = 66 for Atlantic Forest) and 30% for testing the models (N = 17 for Caatinga and N = 28 for Atlantic Forest; Pearson 2007). Data were sampled by bootstrapping with 10 random partitions with replacements. All runs were set with a convergence threshold of 1.0E–5 with 500 iterations, with 10,000 background points.

The logistic threshold output format was used resulting in continuous values for each grid cell in the map from 0 (unsuitable) to 1 (most suitable). These values can be interpreted as the probability of presence of suitable environmental condition for the target species (Veloz 2009). The logistic threshold used to "cut-off" the models converting the continuous probability model in a binary model was the one that assumed 10 percentile training presence provided by the Maxent outputs 0.300 for Caatinga; 0.100 for Atlantic forest. These thresholds were selected by the specialists as the best one to represent the suitable areas for recent jaguar distribution in both biomes.

Models were evaluated by the AUC value, the omission error and by the binomial probability (Pearson 2007).

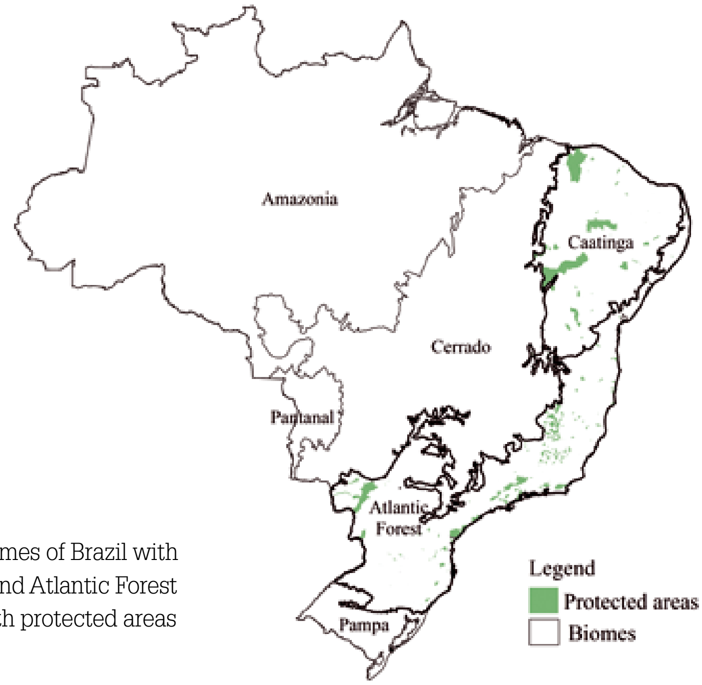

Fig. 1. Biomes of Brazil with Caatinga and Atlantic Forest biomes with protected areas (green).

Results and Discussion

The SDM for Caatinga and Atlantic Forest biomes presented high predictive success and were highly statistically significant (AUC = 0.880 ± 0.027, omission error = 0.206, $p < 0.001$; AUC = 0.944 ± 0.022, omission error = 0.129, $p < 0.001$, respectively; SOM Fig. 1, 2), predicting about 18.64% of the Caatinga (Fig. 3) and 10.32% of the Atlantic Forest (Fig. 4) as suitable for jaguar occurrence.

Much of the Caatinga biome (844,453 km^2) predicted as suitable (54.77%) for jaguar occurrence encompassed the closed to open (>15%) shrubland. Meanwhile, much of the unsuitable area (26.62%) for the species also encompassed this land cover. This discrepancy is due especially to human development or simply occupation that leads to medium to high level of disturbance in the environment. These habitat alterations are especially due to mining activities, agriculture, timber extraction, firewood production, and lowering of prey items due to excessive hunting activities. The closed to open shrubland covers about 40.67% of total biome area. The closed formations have 60% to 80% of plant cover, whereas the open formations have only 40 to 60% (Chaves et al. 2008). The vegetation type is deciduous, generally with thorny woody species > 4.5 m tall, interspersed with succulent plants, especially cacti. The trees are 7-15 m high, with thin trunks. Several have tiny leaves where others have spines or thorns (Andrade-Lima 1981).

The semi-arid Caatinga domain is one of the most threatened biomes in Brazil with less than 50% of its natural cover and greatly impacted and fragmented by human activities (Leal et al. 2005). Most of the protected areas found in this biome (Fig. 3) presented large areas as suitable for jaguar occurrence, such as Serra Branca Ecological Station (ES) and Serra da Capivara National Park (NP) with 100%, Morro do Chapéu State Park (SP) with 91.29% and Serra das Confusões NP with 71.51%. Nevertheless Serra das Confusões and Chapada Diamantina NPs (with 62.63%) are the only two protected areas that are located in transitional areas with the Cerrado biome, hence the lower suitability within the Caatinga. Serra das Confusões NP is indeed a very important area for jaguars as it is large (5,238 km^2), connected to Serra da Capivara NP/Serra Branca ES and also somehow bridges the Caatinga jaguar population with those of the Nascentes do Rio Parnaíba protected areas complex, likely the most important of the Cerrado domain. The bulk of prime areas for jaguars, located within the center of the Caatinga domain are being proposed as a new NP, created to protect one of the most important populations of the Critically Endangered Caatinga jaguar, Boqueirão da Onça NP (Fig. 3). The creation of this new protected area should be of utmost importance for jaguar conservation in the Caatinga. If the NP will be created according to the proposed limits, it will encompass 24.66% of the highly suitable area for jaguars.

Much of the Atlantic Forest biome (1,110,182 km^2) predicted as suitable (27.44%) for jaguar occurrence encompassed the closed to open (>15%) broadleaved evergreen or semi-deciduous forest (55.26%), while unsuitable areas encompassed mainly mosaic cropland (50-70%)/ vegetation (grassland/shrubland/ forest) (20-50%).

Most of the continuous forest remains indicated as suitable for the jaguars at the Atlantic Forest biome correspond to the Brazilian protected areas (Fig. 4) such as Morro do Diabo SP, Mico Leão Preto ES, Caiuá ES, Carlos Botelho SP, Intervales SP, Alto Ribeira Touristic SP and Xitué ES, Iguaçu NP, Serra da Bocaina NP, Tinguá Biological Reserve (BR) and Serra dos Órgãos NP, besides surroundings areas and some isolated forest remains (e.g., Rio Doce SP and Itatiaia NP). The marshlands in the Upper Paraná River, in the west portion of the Atlantic Forest biome, are as important as forest areas to jaguar conservation. The most suitable areas in the region includes continuous protected areas such the Ilha Grande NP, Várzeas do Rio Ivinhema SP and Ilhas e Várzeas do Rio Paraná Environmental Protection Area (EPA).

Some suitable areas indicated by the model such as Cantareira SP and its surrounding did not present any recent record of the species presence. The depauperate quality of forest cover of these areas with high human pressure probably explains the absence of the species there. This clearly illustrates the overprediction (i.e., commission error), frequently observed in SDM. In this particular situation, the degraded vegetation and human pressure are not contemplated in the environmental variables input in the modeling, decreasing

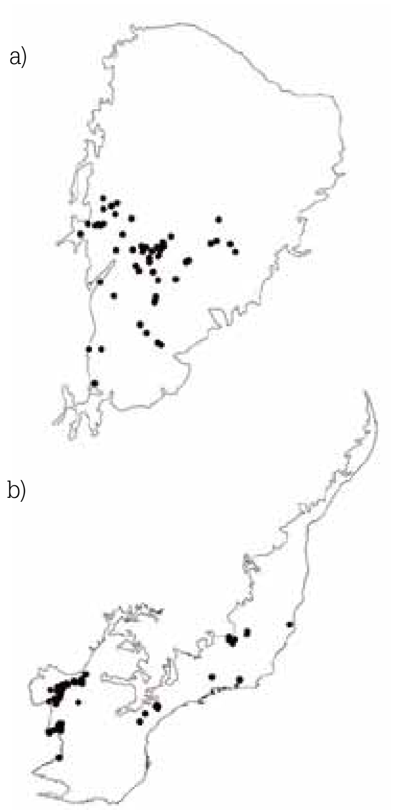

Fig. 2. Jaguar presence points for (a) Caatinga (N = 57) and (b) Atlantic Forest (N = 118) biomes in Brazil.

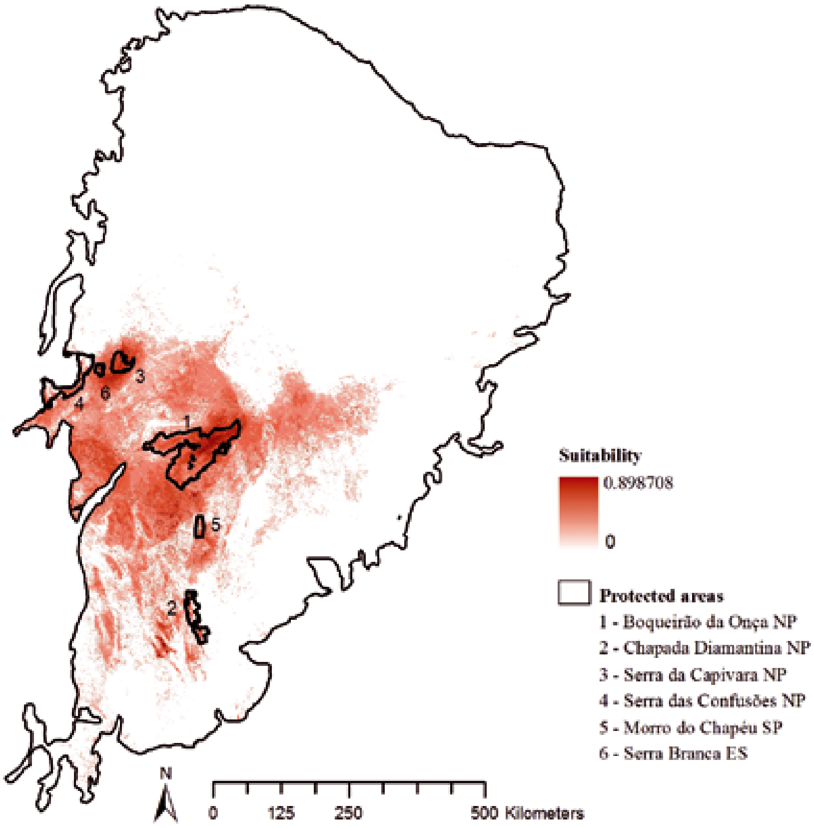

Fig. 3. Potential distribution model for jaguar in Caatinga biome with some protected areas highlighted.

its predictive power. On the other hand, some areas with recent records of the species (not included in the modeling) were not indicated as suitable by the model such as the Juréia-Itatins ES and Caraguatatuba area of Serra do Mar SP. The omission and commission errors are common and frequent in SDM (Fielding & Bell 1997, Pearson 2007), emphasizing the need of cautious interpretation as local characteristics could decrease the model predictive success.

Most of the cropland areas (rainfed croplands, mosaic croplands/vegetation, mosaic croplands/forest; 64.67%) were considered unsuitable for the species occurrence. Jaguars depend on large prey such as peccaries, which are very susceptible to environmental degradation and poaching (e.g. Cullen Jr. et al. 2000), which is intense throughout the Atlantic forest, with the exception of a few well preserved areas. Accordingly, Cullen Jr. et al. (2005) had already verified that jaguars display a strong selection for primary and secondary forests, a strong avoidance of pastures and a weak use of agricultural areas.

The probability of jaguar presence was associated differently to the environmental predictor variables. Elevation (19.03%), the precipitation of driest month (Bio14; 18.08%) and

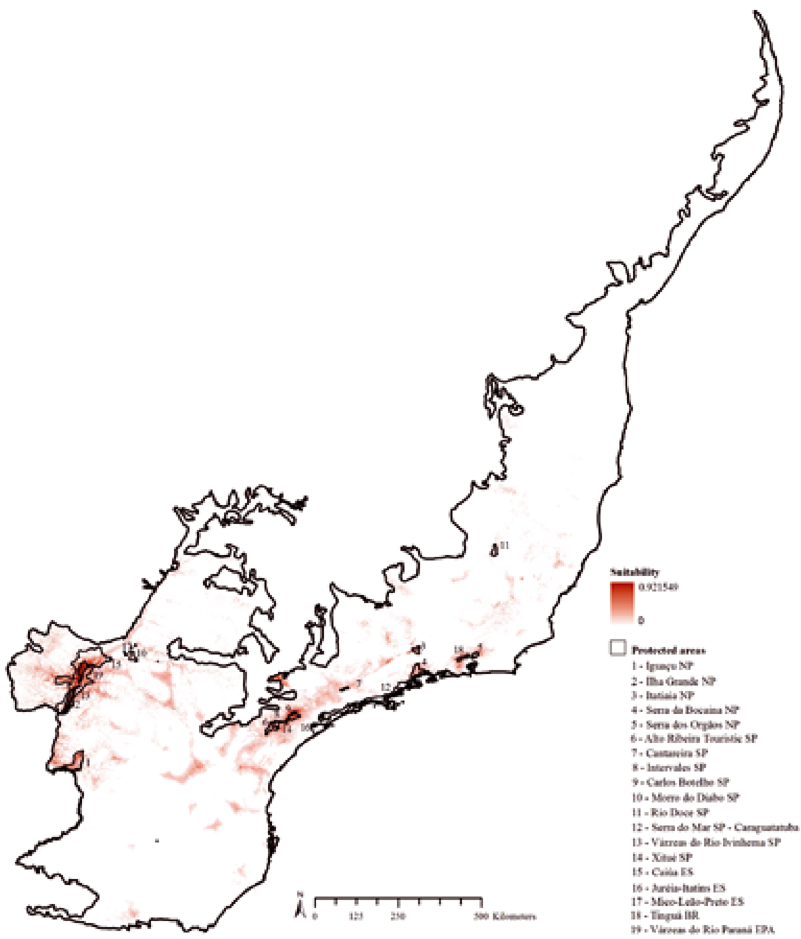

Fig. 4. Potential distribution model for jaguar in Atlantic Forest biome with some protected areas highlighted.

the mean diurnal range (Bio2; 17.25%) were the highest contributor variables for jaguar model at the Caatinga biome. The probability of jaguar presence increased as elevation and the mean diurnal range increased, but decreased as the precipitation of driest month increased (Fig. 5). The presence of jaguar in Caatinga is associated with higher areas probably because of the lower human pressure and more pristine vegetation (e.g., Boqueirão da Onça NP). Although variables Bio14 and Bio2 had important contributions to the model its relationships with jaguar presence were not so clear.

Land cover (41.29%) was the highest contributor variable for the jaguar model in the Atlantic Forest biome. The high probability of jaguar presence was related to the closed to open (>15%) grassland or woody vegetation regularly flooded (Fig. 6). Wetland areas and riparian vegetation (Fig. 7) are core areas and dispersal corridors for jaguars (Cullen Jr. et al. 2005). However, only 30% of the original area of the Paraná River is left because of the construction of hydroelectric power stations (Agostinho & Zalewski 1996).

Future for SDM as a tool for cat conservation

The field of SDM is promising for improving conservation efforts and priorities (e.g. Thorn et al. 2009, Costa et al. 2010, Marini et al. 2010). SDM is a useful tool for resolving practical questions in applied ecology and conservation biology, but also in fundamental sciences (e.g. biogeography and phylogeography) (Guisan & Thuiller 2005). It represents an empirical method to draw statistical inferences about the drivers of species' ranges under different conservation, ecological and evolutionary processes (Zimmermann et al. 2010).

The SDM approach can improve our knowledge about cat species worldwide by 1) highlighting areas where the species might occur but confirmed observation is missing, 2) identifying gaps in data collection and guiding the sampling efforts, 3) identifying key areas for conservation efforts and potential corridors linking protected areas and/or populations, 4) contributing for the assessment of IUCN red list categories, 5) helping to reduce conflicts (e.g., zoning), among others. Moreover, this modeling technique can provide a comprehensive understanding of the historical, current and future ranges of cat species, providing insights to conservation planning (e.g., Marini et al. 2010). Modeling should also be of paramount importance for predicting threatened species range in a world of climatic change. In fact, this kind of prediction could be vital for setting proper and effective action plans for critically endangered populations/species.

In practice, one of the most useful contributions from SDMs could be the prediction of suitable areas for species occurrence as well as helping to delineate potential corridors which link populations on a continental scale. The environmental suitability maps in a modeling framework could be used as a basis to improve the already existing extraordinary initiatives that seek to create such linkages (e.g. jaguar corridor initiative). This, in turn, has been considered one of the most effective conservation strategies to guarantee cat species conservation (Macdonald et al. 2010).

The assessment of conservation priorities for felids should consider the environmental suitability of landscape in a modeling framework. Suitability maps could be considered by stakeholders for defining priority areas for the establishment of new protected areas or corridors. However, conservation inferences should rely on robust models, avoiding omission and overprediction in species distribution range.

The modeling exercise defining priority areas for conservation efforts should be a useful first evaluation. In this workshop one of the most valuable contributions of this exercise was the participatory manner in which this model was constructed. Furthermore the resulting maps provided stakeholders with distribution information and clear results to discuss, and it stimulated debates and discussions which otherwise may not have occurred. However, for reliable conservation decisions suitability models must rely on well-delineated field inventories (Costa et al. 2010) and model results must be validated.

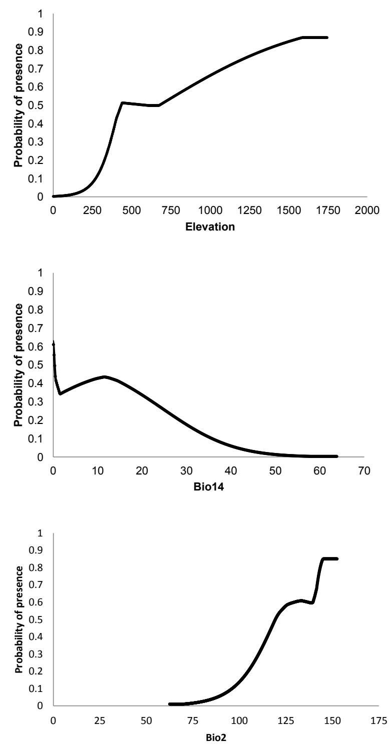

Fig. 5. Marginal response curves of the predicted probability of jaguar occurrence at the Caatinga biome for the environmental predictor variables that contributed substantially to the SDM.

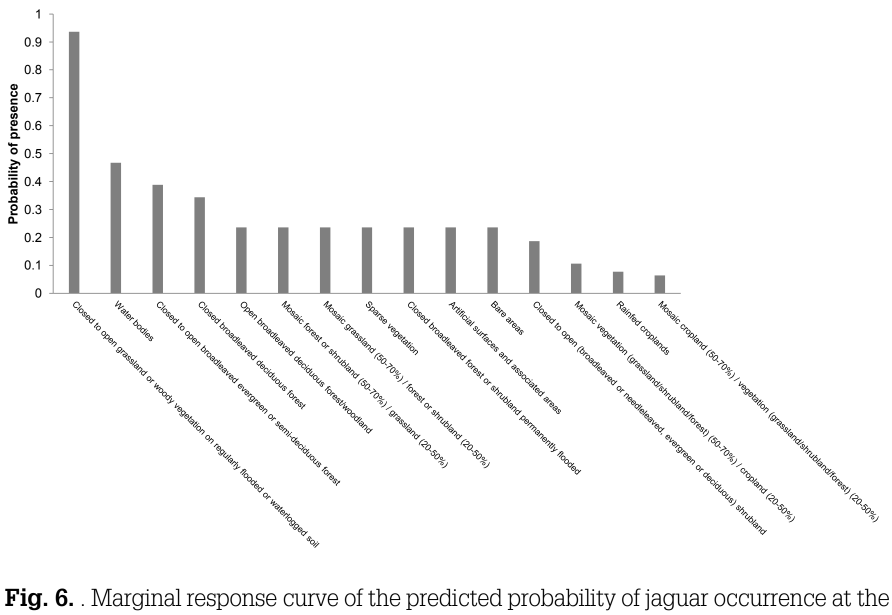

Fig. 6. . Marginal response curve of the predicted probability of jaguar occurrence at the Atlantic Forest biome for the environmental predictor variable that contributed substantially to the species distribution model.

Fig. 7. Riparian vegetation is an important part of jaguar core areas and corridors (Photo A. Gambarini),

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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 km^2 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-

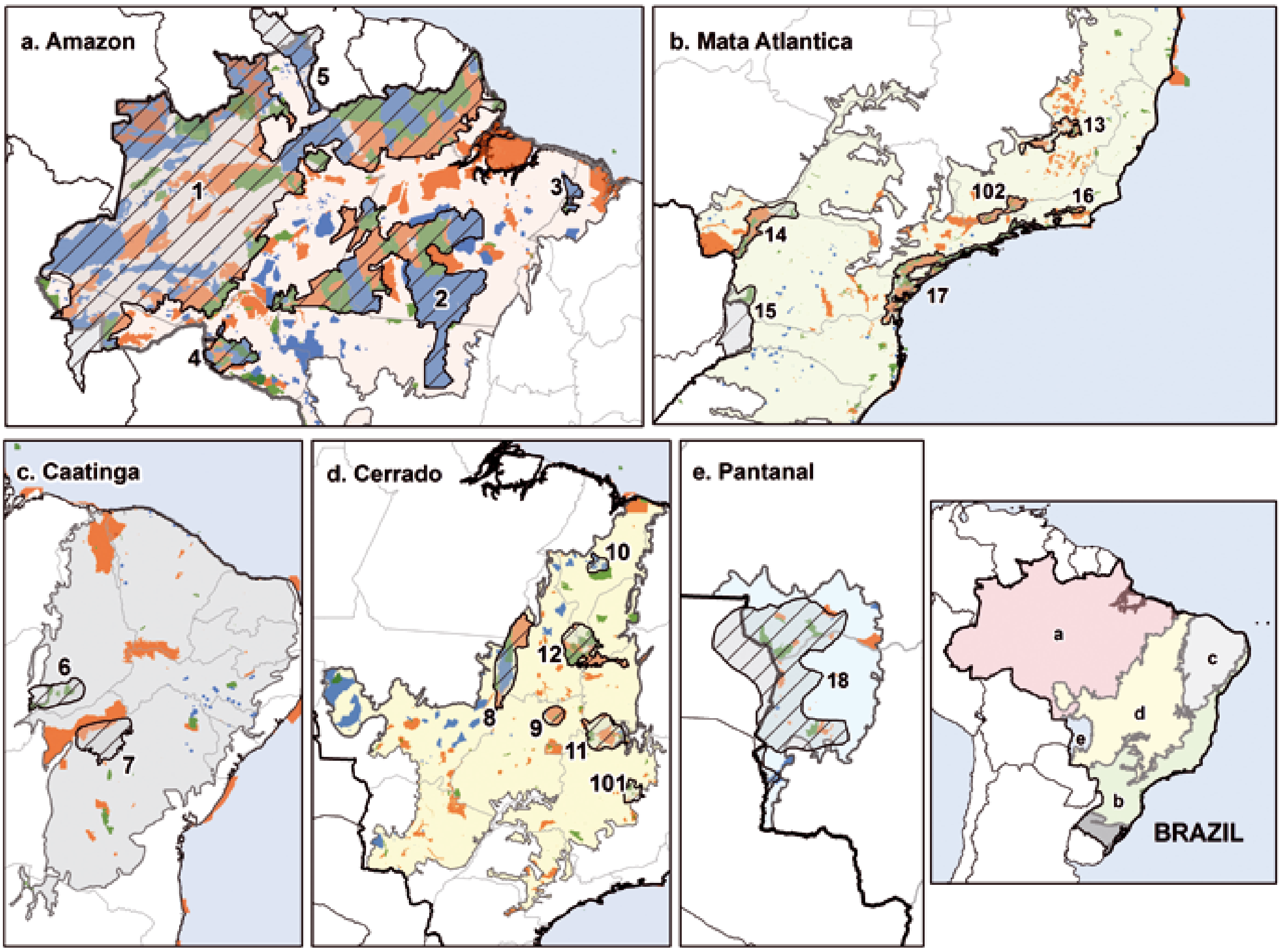

Fig. 1. Jaguar Conservation Units (black hatched polygons) in five biomes in Brazil. JCU IDs correspond to the IDs in SOM Table 1. Red: Restrictive-use forest reserves including state forests, national forests, extractive reserves, natural monuments, municipal natural parks, wildlife refuges, natural 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

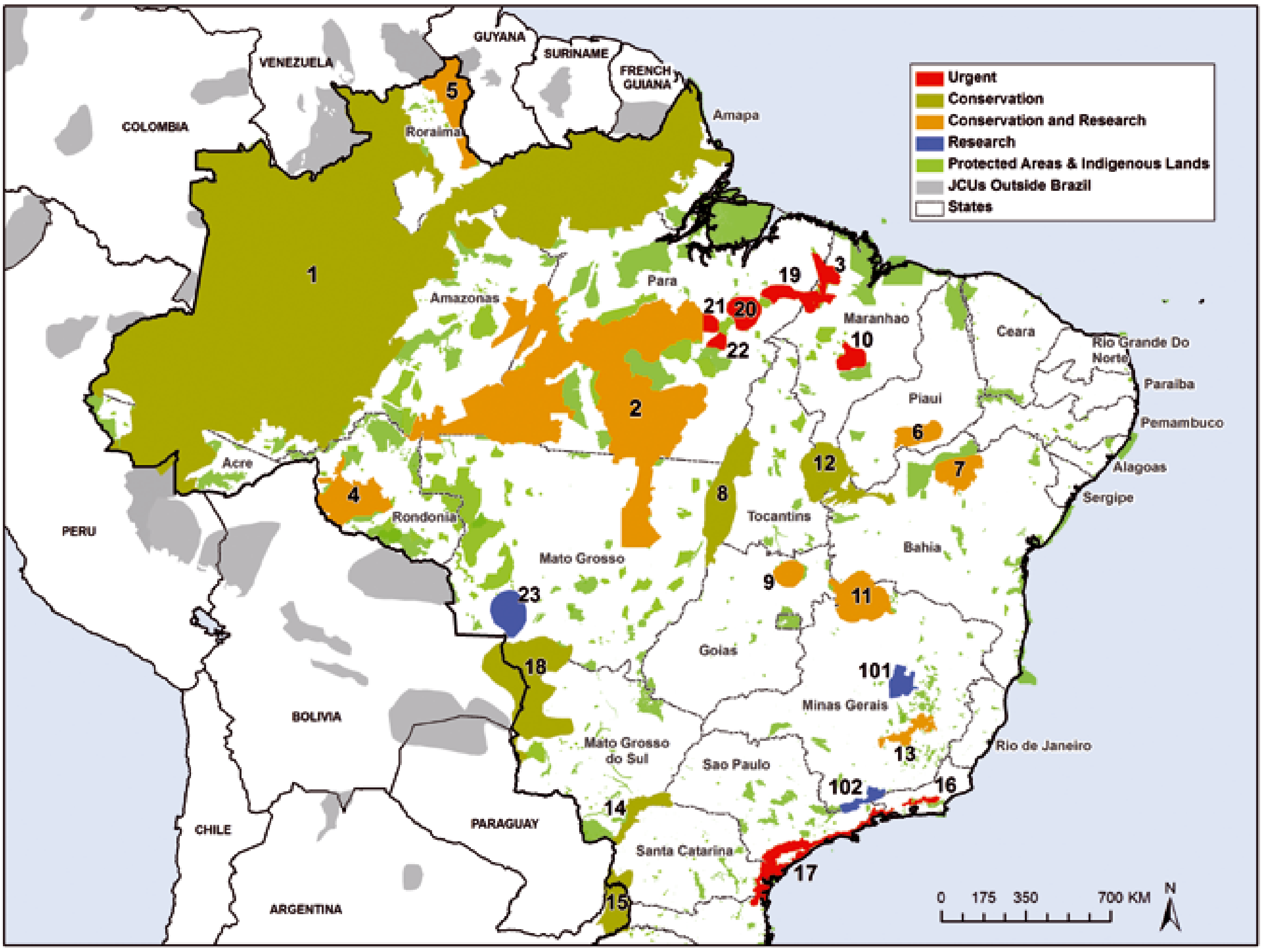

Fig. 2. Priority areas in Brazil and their action categories.

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 management 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.

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