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Chapter 19

THE JAGUAR CORRIDOR INITIATIVE: A RANGE-WIDE CONSERVATION STRATEGY

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ABSTRACT

The jaguar (*Panthera onca*) is the largest cat in the New World and faces threats including direct persecution, habitat loss, and decimation of prey populations. Typically, conservation approaches focus on individual sites and do not account for larger landscape dynamics over the range of the jaguar. Furthermore, conservation programs tend to remain internal to the organization in which they were born. However, expanding beyond this insular approach to jaguar conservation can have much broader impacts and result in lasting conservation programs. We present a range-wide strategy for jaguar conservation, seeking general acceptance and use by the conservation community. Working together on a single, range-wide framework allows us greater opportunity to advance jaguar conservation. Our strategy, the Jaguar Corridor Initiative (JCI), is built upon previous range-wide priority setting exercises that identified core jaguar populations. In this chapter, we explain how we incorporated corridors connecting these populations to allow for jaguar dispersal and genetic exchange, thereby adding a critical element to the long-term survival of this species. We then describe how we are assessing the jaguar populations and corridors in the field. These empirical data provide further scientific backing to the areas identified in the conservation network, allow for refinement, and give a baseline from which monitoring can occur. Finally, we describe our conservation efforts across the JCI. The large size of the JCI necessitates working at all levels of engagement, from the national level to the local landowner. Furthermore, each site in the JCI faces different challenges, so varying conservation approaches must be used across jaguar range to result in lasting conservation success. We provide examples of conservation efforts with the hope that other biologists and conservation practitioners across jaguar range will embrace the JCI and build off our beginnings. We have an opportunity to ensure an enduring future for jaguars by preemptively preventing fragmentation, thereby maintaining connected populations and allowing the biology and ecology of the jaguar to be preserved. This can only be accomplished through collaborative and transparent approaches across the range of this species.

Keywords: *Panthera onca*, range-wide priority setting, rancher outreach, monitoring, detection/non-detection, environmental policy

INTRODUCTION

The jaguar (*Panthera onca*) is the largest terrestrial carnivore in Latin America and is both revered and feared by the people of the region. This duality of feelings towards the jaguar has resulted in the persecution of jaguars even as they have been elevated to an iconic species of conservation significance. However, persecution isn't the only threat jaguars face. Habitat destruction and decimation of prey populations are pushing the jaguar closer towards extinction.

We are at a critical moment in the conservation of the jaguar. We still have the opportunity to conserve jaguars and their full suite of natural ecological and biological processes across their entire current range, from birth and dispersal, to breeding and survival. This opportunity is all too scarce for most other large carnivores. The tiger, and conservation initiatives surrounding this species, provide an insightful example for those of us working on the other side of the planet.

The tiger once occupied over 16 million km^2 of Asia. Currently, tigers range in, at most, 7% of their historic habitat (Sanderson et al. 2006). At some point, the decline of the tiger hit a threshold where loss of tiger populations increased dramatically. It has been estimated that by 2005, tiger range decreased 40% from 1995 levels (Dinerstein et al. 2006). This level of deterioration spun tiger conservation into a state of triage, making recovery efforts difficult at best.

Pinpointing the exact reason for this precipitous decline is complicated. However, what is clear is that conservation intentions and actions were not focused enough to adequately address threats to tigers throughout most of their range. The current state of the jaguar is much more hopeful. Jaguars, classified as Near Threatened (IUCN 2009), once occupied over 19 million km^2 of Latin America. As of 2006, they occupied 61% of this historic range (Zeller 2007). Granted, today the jaguar's range is likely smaller, but with foresight and strategy we can prevent an irreversible decline in jaguar numbers -- even in the face of an exponentially increasing human population and one of the highest deforestation rates in the world.

In this chapter, we present a range-wide conservation strategy that seeks to conserve 90 jaguar populations and over 180 jaguar corridors across all 18 countries where jaguars currently exist. This jaguar conservation network measures 4.5 million square kilometers – a goal which, if accomplished, would put the jaguar well above where tigers were in 1995 and would unite researchers and conservation practitioners around a single, focused goal.

We begin by summarizing the range-wide conservation strategies developed for the jaguar and our arguments for augmenting these range-wide strategies with corridors. We then introduce the Jaguar Corridor Initiative and its five staged approach.

1.1. Need for Range-wide Conservation

There are myriad reasons for developing range-wide conservation strategies. It has long been recognized that protected areas in themselves are not sufficient for the conservation of many large mammals. Even the largest protected areas in East Africa and North America are too small and isolated to maintain healthy populations of wide-ranging species (Newmark 1987; Newmark 1995; Gurd et al. 2001). Moreover, focusing conservation on a small number of discrete protected areas across the entirety of a species' range does not prevent the persistent contraction of their geographic distribution (Sanderson et al. 2002).

Scaling up our perspective allows us to identify ecological distinctions across a species' range and to target populations that have unique behavioral, demographic, and ecological characteristics (Wikramanayake et al. 1998). This approach elevates ecology above political divisions, so we can examine a species' needs regardless of whether a population spans an international border or is thriving beyond the boundaries of a national park.

A range-wide perspective also allows for the identification of large-scale patterns of threats and anthropogenic development, helping us determine which areas are most highly threatened today, and predict which areas will face significant threats in the future. Finally, range-wide planning may be important in preventing extinction due to a changing climate. Species that are more widely distributed and occupy a diverse climactic envelope are less threatened by climate change (Harte et al. 2004; Barnosky 2008; Faith & Surovell 2009).

In 1999, the Wildlife Conservation Society (WCS) and the Universidad Naciónal Autonoma de México brought together 35 jaguar experts from throughout jaguar range. The objective was to reach a consensus on the first range-wide research and conservation plan for the jaguar (Sanderson et al. 2002). Also known as a Range-wide Priority-Setting (RWPS) exercise, this was the first step in shifting the traditional conservation paradigm from focusing on discrete populations to considering how aggregate populations contribute to the survival of the jaguar across its entire geographic range. In a hierarchical framework, experts identified areas of knowledge, the geographic distribution of the jaguar, and core populations of jaguars, or Jaguar Conservation Units (JCUs). The JCUs were prioritized based on a population's ecological importance across jaguar range.

The 1999 exercise raised awareness on the paucity of data on jaguars -- both biologically and in certain geographic regions. This resulted in an exponential increase in jaguar research and spurred interest in an update of the 1999 data set. In 2006, WCS conducted a remote survey of 110 jaguar experts from the U.S. to Argentina to collect the same information from the 1999 survey: areas of expert knowledge, current jaguar range, and JCUs. A second prioritization of JCUs was conducted and a new range-wide conservation strategy was proposed (Zeller 2007).

1.2. Augmenting the Range-Wide Strategy

In those years between the RWPS exercises, two genetic analyses were conducted on jaguars. Their results changed our thinking about the RWPS approach. Eizirik and co-authors (2001) published a study that analyzed jaguar genetic samples from throughout jaguar range. The results indicated little evidence of significant geographical partitions between jaguar populations or barriers to gene flow range-wide (Eizirik et al. 2001). This research was further supported after an analysis on two supposed subspecies in Colombia revealed high genetic diversity and gene flow between the populations (Ruiz-Garcia et al. 2006). These analyses provided a clear and compelling argument for corridors to be included in the RWPS exercise in order to maintain the high level of gene flow across jaguar range.

Corridors have been shown to strengthen efforts to protect species and habitats by maintaining or enhancing connectivity between populations (Noss et al. 1996; Crooks & Sanjayan 2006; Gilbert-Norton et al. 2010). Connectivity can contribute to the survival of species by allowing for the dispersal of individuals from their natal ranges to new territories, which, in turn, facilitates the exchange of genetic material among otherwise isolated populations. Without genetic exchange, genetic drift and inbreeding can occur (Soulé & Mills 1998; Young & Clarke 2000). Other negative consequences include potential deleterious effects on sperm production, mating ability, female fecundity, and juvenile survival (Frankham et al. 2002). Such effects can eventually compromise the ability of individuals to adapt to changing conditions and climate (Saccheri et al. 1998; Lehmann & Perrin 2006), reduce fitness, and contribute to extinction risk for a population (Frankham 2005). In facilitating the movement of individuals between populations, corridors may also play a role in ameliorating the negative effects of demographic and environmental stochasticity (Brown & Kodric-Brown 1977; Hilty et al. 2006).

Furthermore, corridors may be vital for species persistence by allowing for range shifts in response to climate change (Noss & Daly 2006; Soulé et al. 2006; Krosby et al. 2010). Thomas et al.'s (2004) climate change simulation experiment projected a drastically lower number of extinctions when dispersal habitat was available, compared to scenarios without dispersal habitat.

In addition to the important roles corridors play in species survival, the incorporation of corridors allows us to monitor and address habitat fragmentation across a species range. RWPS exercises have no method by which to account for large disturbances outside of JCUs; these disturbances may ultimately affect species survival by leading to irreversible habitat loss and isolation of populations.

The traditional RWPS exercises also did not account for the importance of populations based on their location in a network or meta-population. When corridors are considered, a linked, geographic network is formed that can make range-wide conservation planning more effective and conservation strategies more meaningful (Keitt et al. 1997). Populations and corridors that are essential to maintaining the connectivity of the network can be identified, the prioritization scheme from RWPS exercises can be enhanced, and isolation of populations can be prevented.

A network perspective may also highlight the importance of small populations in maintaining network connectivity, which have traditionally been given a low priority in RWPS exercises.

1.3. The Jaguar Corridor Initiative, a Five Staged Approach toward Range-wide Conservation

In this chapter, we describe the process of developing and implementing Panthera's Jaguar Corridor Initiative (JCI). We believe the JCI is truly a range-wide approach to long-term jaguar conservation and provides a platform from which many independent biologists and conservationists can work towards the same goal.

We begin by describing the creation of the JCI—specifically, how we analyzed the range of the jaguar for connectivity between JCUs and how we incorporated these corridors into the RWPS framework. We then describe how we used three prioritization schemes to identify important areas for on-the-ground research and conservation efforts. This is followed by a description of how we validate and, if necessary, refine the JCUs and corridors with empirical data. We then discuss various conservation efforts we have used to date – from acquiring support from the highest governmental level to working with the smallest landowner. Then, we discuss our monitoring strategy.

At its simplest, the JCI is a five stage process for conservation where we 1) identify the conservation areas, 2) prioritize those areas, 3) verify and refine the areas using the prioritization results, 4) implement conservation efforts in those areas, and 5) monitor our conservation efforts and other activities.

2. Development of a Range-wide Jaguar Conservation Network

2.1. Identification of Jaguar Conservation Units

The JCUs form the backbone of the jaguar conservation network. We used the updated JCUs from the 2006 RWPS exercise. In that exercise, experts were asked to identify JCUs that fell into one of two categories: Type I JCUs: 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 2 JCUs: areas containing fewer jaguars, but with adequate habitat and a stable diverse prey base, such that jaguar populations in the area could increase if threats were alleviated (Sanderson et al. 2002). JCUs were not restricted to or required to contain protected areas.

The boundary of each JCU was delineated by the experts by drawing a polygon on paper maps provided for this purpose. For each JCU, experts were required to submit information on population size, population status, habitat quality and connectivity, important prey species, threats, and land tenure. The JCU polygons were digitized and attributed with the descriptive information. This resulted in 90 JCUs ranging in size from 211 km^2 in northwestern Ecuador to 99,574 km^2 in central Brazil (Figure 1a) (Zeller 2007). In total, the JCUs covered 1.9 million km^2, or 16% of current jaguar range. Forty-six JCUs were classified as Type 1, 38 were classified as Type 2, and six JCUs did not have enough data to confidently classify them into one of these two categories (Zeller 2007).

2.2. Identification of Jaguar Corridors

Corridors can be identified in a number of ways, from the 'seat of the pants' approach to the most complex and spatially explicit individual-based models (Noss & Daly 2006). Because of the large scale of our study area and the lack of empirical data on jaguar movement during dispersal events, we chose to identify linkages between JCUs with a least-cost corridor model (Adriaensen et al. 2003).

Least-cost corridor models are simple enough to allow the use expert opinion for estimating resistance of landscape features, yet are detailed enough to predict functional areas of connectivity. Functional connectivity takes into account both landscape structure and the response of individuals to this landscape structure (Pither & Taylor 1998). The foundation for most least-cost corridor models is a grid-based matrix which quantifies the landscape into varying levels of resistance, or costs, to movement (Bélisle 2005; McRae 2006). The matrix is constructed by assigning a movement cost to each chosen landscape element (Ray et al. 2002).

Using such a matrix allows us to expand beyond the simple notion of habitat connectivity, where two patches are connected by a swath of similar habitat, by quantifying all the varying landscape features that a large carnivore such as a jaguar might use (Singleton et al. 2002). The use of certain anthropogenic landscape layers also allows us to incorporate the notion of safety and survival into the matrix. After constructing the landscape matrix, a least-cost-corridor analysis can be performed between populations.

Using ArcGIS v9 software, we chose six GIS-based landscape characteristics considered to most affect jaguar movement and survival: land cover type, percent tree and shrub cover, elevation, distance from roads, distance from settlements, and human population density. Land cover class, percent tree and shrub cover, and elevation are closely related to movement behavior in most large mammal species (Carroll et al. 2003; Naves et al. 2003; Dickson et al. 2005), whereas distance from roads, distance from settlements, and human population density were considered to be correlated with human persecution of jaguars, including direct mortality (Naves et al. 2003; Rabinowitz 2005; Woodroffe et al. 2005).

Since empirical data on jaguar dispersal was not available, we asked 15 jaguar experts throughout jaguar range to assign cost values to the attributes of the individual landscape layers based on how costly a particular attribute would be to jaguar movement. Cost values ranged from 0 (no cost to jaguar movement) to 10 (a high cost for jaguar movement). Attributes could be assigned an N/A if the physical characteristics of that cell would prevent a jaguar from moving through it. Experts also provided a value representing the cumulative cost of all the layers beyond which a jaguar would not likely travel. We averaged the values across the jaguar's range to obtain an overall movement cost for the attributes of each landscape (For cost values, please refer to Table 2 in Rabinowitz & Zeller 2010). Movement costs were then applied to each cell of the six grids and the grids were combined into one layer using the Raster Calculator. To create the final cost surface, we reclassified the output from the Raster Calculator so that all the pixels whose sums were above 25 (the average cumulative score indicating a barrier to movement) represented a break in the matrix.

To determine optimal routes of travel across the cost surface, we calculated cost-distance matrices from each of the 90 JCUs. Cost-distance grids between all proximate pairs of jaguar populations were combined to identify the least-cost corridors. We combined all overlapping corridor grids into one final corridor layer and extracted the lowest 0.1% of grid cell values to identify the final jaguar corridors.

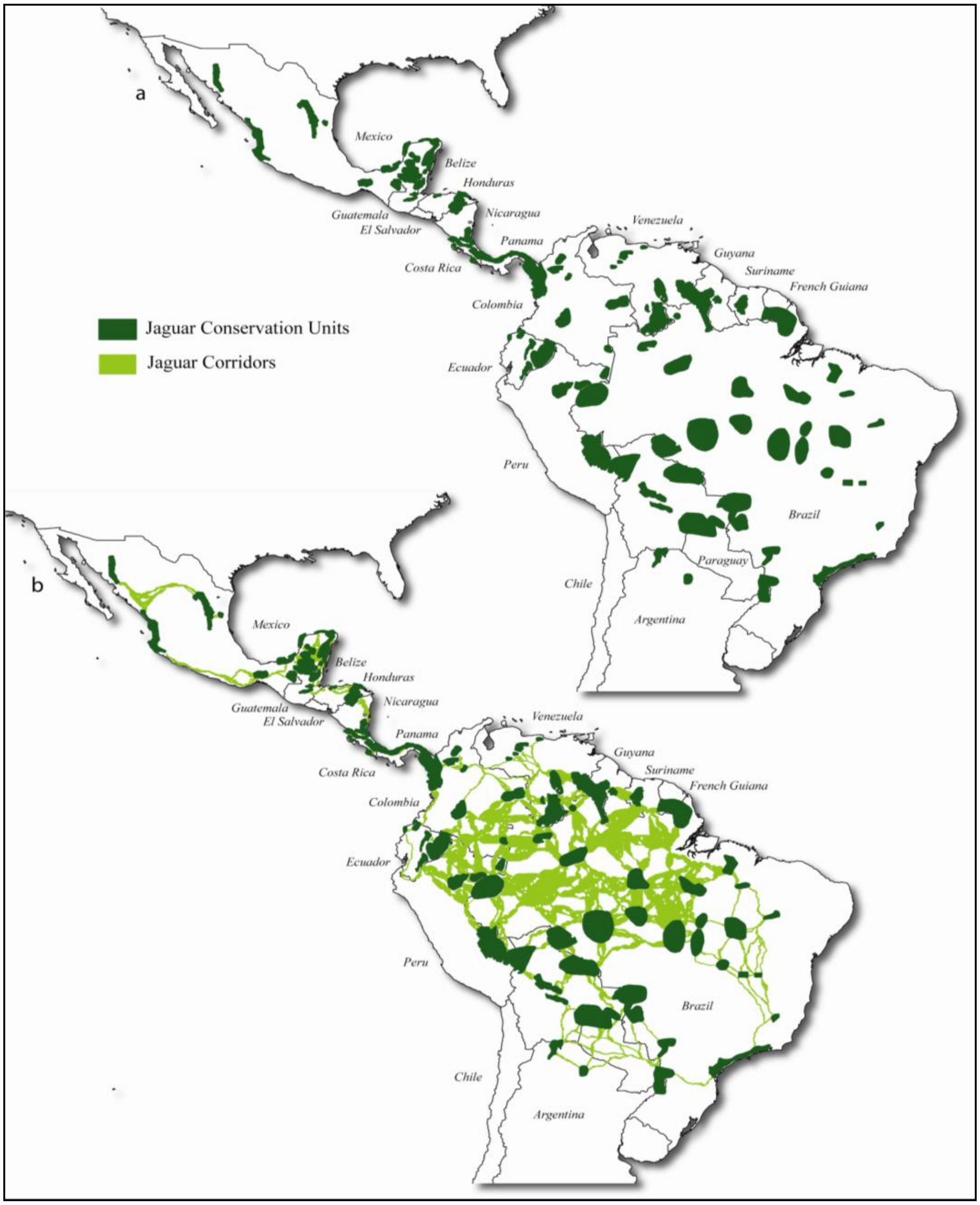

Figure 1. Jaguar Conservation Units and jaguar corridors.

The least-cost corridor analysis resulted in corridors connecting all 90 JCUs except two, between the Sierra de las Minas JCU in southern Guatemala and the Pico Bonito/Texiguat JCU in north central Honduras. Figure 1b portrays the 182 resultant corridors, which cover 2.6 million km^2 (Rabinowitz & Zeller 2010). For Mexico and Central America, the average corridor length between known jaguar populations is 174.42 km (range: 3 - 1102 km) compared to South America, where the average corridor length is 489.14 km (range: 12-1607 km).

3. Prioritization

The JCUs and corridors cover a combined area of 4.5 million km^2. In order to focus research and conservation efforts across this vast region, we prioritized JCUs and corridors using 3 different prioritization processes, ecological importance, network importance, and corridor vulnerability.

3.1. Ecological Importance

The ecological importance prioritization was taken directly from the 2006 RWPS exercise (originally developed in the 1999 exercise as described by Sanderson et al. 2002) and ranks the JCUs in terms of their ecological importance. JCUs were separated by eco-region and the JCUs in each distinct eco-region were ranked against one another in terms of their ability to provide for long-term jaguar conservation. JCUs that had large areas, stable or increasing populations, good quality habitat, frequent dispersal, and little or no hunting, were ranked higher than other JCUs in their eco-region. This resulted in 32 JCUs that had the highest possible rank in terms of ecological importance (Figure 2a) (Zeller 2007). These JCUs represent 32 of 36 distinct geographic regions across the jaguar's historic range. Jaguars are considered extirpated in the other 4 eco-regions (Zeller 2007).

3.2. Network Importance

The second prioritization scheme was based on the importance of JCUs and corridors in maintaining connectivity across the entire conservation network. Important connectors, or network 'hubs', if lost, would have severe negative consequences for the JCI.

To identify these network hubs, we used CONEFOR Sensinode 2.2 software to calculate the integral index of connectivity (IIC) and the change in IIC (dIIC) for each JCU (Pascual-Hortal & Saura 2006; Saura & Pascual-Hortal 2007). The IIC calculates the extent of habitat connectivity in a network, incorporating the area of each population and the number of links between populations. The dIIC for a population is simply the change between the original IIC value and the IIC value of the network when that population is removed. The higher the dIIC value, the higher the importance of that JCU for maintaining the network (Pascual-Hortal & Saura 2008).

We then identified corridors that were important for maintaining the connectivity of the network. Any corridor that was the sole linkage to a population with a high dIIC value was also considered a priority since losing these connections would also result in severing the connectivity of the network.

The network importance analysis resulted in dIIC values ranging from 1-20 (median 2.75). For prioritization purposes, we chose all 23 populations above the 75th percentile as being the most important for maintaining the integrity of the network. The JCU that ranked the highest in importance was the Choco-Darien JCU spanning the border of Panama and Colombia. Of the highest ranked JCUs, 18 were in Mexico and Central America and the rest were in South America. Any corridors that were the sole linkage for a JCU with a high dIIC value were also prioritized as being important for maintaining the integrity of the network. This resulted in 13 corridors, all located in Mexico and Central America (Figure 2b).

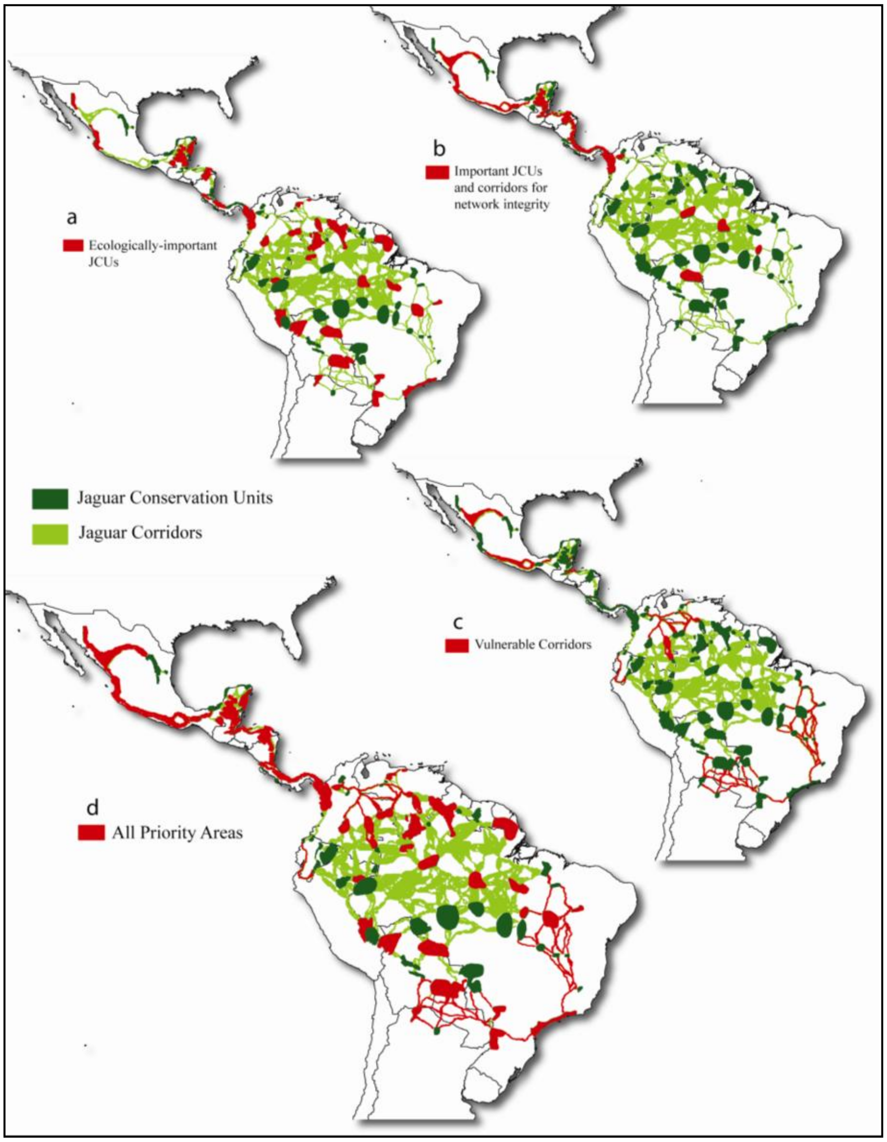

Figure 2. Results of prioritization analyses. Figure *a* shows the ecologically important JCUs. Figure *b* represents JCUs and corridors that are important for maintaining the overall conservation network. Figure *c* shows the vulnerable corridors. Figure *d* displays all the priority areas across jaguar range.

3.3. Corridor Vulnerability

The corridor vulnerability analysis was based on the width of the corridors. While no empirical data exist on the width at which corridors fully lose their functionality, corridor width likely becomes more important as the corridor length increases. Beier (1993) suggested cougar corridors should be at least 400 m wide, while Florida panthers are estimated to have much wider corridors (3-7 km) (Kautz et al. 2006). Therefore, as a conservative measure, we identified any corridor that measured less than 10 km in width at any point along its length as vulnerable to being lost.

We identified 44 corridors that were vulnerable to being lost. Including the Guatemala/Honduras connection, five of these corridors were in Central America and Mexico and 39 were in South America (Figure 2c).

3.4. All Priority Areas

We combined the three priority classes to identify all areas of conservation importance across jaguar range. Figure 2d shows the assemblage of all three priority categories described above. There were eight JCUS that were both important for the integrity of the network and are important ecologically. There were nine corridors that were both vulnerable to fragmentation and important for network integrity. Clusters of JCUs that are important for connectivity, JCUs that are a priority ecologically, and corridors that are vulnerable are found in the extreme northern and southern parts of jaguar range as well as in Central America and Colombia. It is not surprising that connectivity hubs are concentrated in Central America. Spread along an already-restricted isthmus, JCUs and corridors mostly form a single chain, which, if broken, would divide the network. Furthermore, Colombia's importance is highlighted as the natural link between Central and South America and across the Andes.

The maps and analyses presented here represent a practical range-wide conservation strategy for the jaguar as well as a platform for regional and site-based actions for the species. These priority areas have formed the basis for our on-the-ground research and conservation activities, described in more detail below.

4. Field Validation

The RWPS exercise and the corridor analysis were, necessarily, both broad stroke analyses. Though they are invaluable for providing a range-wide perspective, they may fall short on detail and accuracy when taking a closer look at individual sites. Both range-wide analyses were based on expert opinion. Expert opinion is often more prone to error than empirical data in modeling species distribution and in identifying resistance values for corridor analyses (Pearce et al. 2001; Clevenger et al. 2002; Seone et al. 2005; Beier et al. 2008; Pullinger & Johnson 2010). In addition, remotely sensed data are prone to misclassification and resolution issues and are often outdated. Therefore, field-based assessments are necessary to further refine JCU and corridor boundaries. Field assessments are also essential to confirm the use of the corridor by jaguars, allowing us to determine its appropriateness (Hilty et al. 2006; Noss & Daly 2006).

We have developed research protocols for assessing JCUs and corridors in the field. We designed the protocols to collect empirical data to make these areas more scientifically defensible, and to obtain a baseline from which to monitor future conservation activities.

Both protocols are based on a detection/non-detection framework where occupancy modeling can be used to determine probability of habitat use by jaguars and their prey (MacKenzie & Nichols 2004). In recent years, site occupancy modeling has become increasingly useful to ecologists because the only data requirements are based on the detection or non-detection of a species over several sampling occasions (Linkie et al. 2007; MacKenzie et al. 2002; Weller 2008) and it provides for detection probability. Nocturnal and cryptic species, such as the jaguar, are not always detected when present and failure to incorporate detection probabilities can produce biased estimates, and lead to misguided conservation decisions (Gu & Swihart 2004; Linkie et al. 2007; MacKenzie et al. 2006). Site occupancy modeling also provides a flexible framework that enables occupancy to be modeled as a function of covariate information (MacKenzie et al. 2002). The use of covariates, such as land cover type, elevation, and human presence, can provide valuable information about the factors influencing habitat use by jaguar and prey species in a human-modified landscape.

Sampling design for both JCUs and corridors is based on a sampling grid where sampling unit size is equivalent to the average home range size for jaguars in that area. For the corridor assessment, we generally perform a land cover classification of recent satellite imagery to identify patches of forest and possible areas of connectivity between JCUs the least-cost corridor analysis may have omitted. We include these forest patches in the study area in order to assess, and possibly include, other areas that may offer comparable dispersal habitat.

4.1. Field Assessment of Jaguar Conservation Units

The JCU assessment consists of 4 main objectives: 1) determine the probability of habitat use for jaguars and prey across the JCU, 2) refine the boundaries of the JCU, 3) obtain estimates of jaguar density across major habitat types in the JCU, and 4) perform a comprehensive threats assessment.

The first objective is met by conducting a detection/non-detection survey in each sampling unit. Depending on the size of the JCU, stratified random sampling of a sub-set of sampling units may be used, though at the very least, 50% of sampling units are to be surveyed for large JCUs and 70% of sampling units are to be surveyed in smaller JCUs (Brashares & Sam 2005). Detection/non-detection data is collected through either the use of camera traps (e.g. Linkie et al. 2007), sign transects (e.g. Guillera-Arroita et al. 2011), or interviews with local residents (e.g. Zeller et al. 2011). Choice of data collection method is dependent on equipment, time, access, and other constraints. The data are analyzed within an occupancy model to determine the probability of habitat use for jaguars and their main prey items.

Probabilities of habitat use for our target species are used to achieve the second objective, refining the boundaries of the JCU. We assume that the core of a JCU will have a high probability of habitat use by jaguars and their prey. As one moves form that core area outward into areas that are more accessible and under increasing levels of human influence, probabilities of habitat use will likely decline. Because we are in the initial phases of piloting the JCU assessment protocol (in JCUs in Brazil and Costa Rica), the threshold at which an area goes from becoming a JCU to a non-JCU is yet to be determined. In some cases this may be an obvious hard boundary; in other cases it may be appropriate to designate a buffer between core JCU habitat and non-JCU habitat.

Camera trap surveys are conducted in each major habitat type in a JCU to acquire density estimates and indices of abundance for each JCU. Camera trap surveys are designed following recommendations in Silver et al. (2004). Estimates based on both 1/2 the mean maximum distance moved (MMDM) and the full MMDM will be calculated (Soisalo & Cavalcanti 2006).

Threats to jaguars and prey are recorded as they are encountered during detection/non-detection and camera trap surveys. Type of threat (logging, grazing, shifting agriculture, plantations, mining, hunting), description of threat, and location are recorded.

The JCU assessment results in a refined JCU with data on probabilities of presence for jaguars and their main prey throughout the JCU, jaguar densities in the major habitat types, and the identification of threats in a spatially rigorous manner. The data serve as empirical evidence for designation of an area as a JCU and the probabilities of habitat use and density estimates will provide baselines for future monitoring of the JCU. Furthermore, the threats assessment identifies which areas are affected by certain types of threats, allowing for targeted conservation interventions and law enforcement activities.

4.2. Field Assessment of Jaguar Corridors

The jaguar corridors present a unique challenge for field surveys in that they traverse mostly private lands between protected areas. These private lands vary in size from small landholdings to large ranches or plantations. Because of this, it is often not practical to use conventional detection/non-detection techniques such as camera trapping or line transects. Theft or tampering of cameras, high human traffic, private land ownership, and, in very large corridor areas, the need for large amounts of staff time and funding are some of the obstacles to collecting data using these methods. Therefore, we developed a protocol for collecting detection/non-detection data through interviews with local people (see Zeller et al. 2011 for full description of protocol).

Local people can be good sources of information about the presence or absence of wildlife (Rabinowitz 1997; White et al. 2005). Well-designed interviews can provide a credible, cost-effective alternative to large-scale field surveys for direct observation or sign of a species, especially for species that are rare and difficult to detect in a short survey period (Berg et al. 1983; Pike et al. 1999; Lariviére et al. 2000; van der Hoeven et al. 2004).

We developed a standardized questionnaire to gather detection/non-detection data on jaguars and their most important prey species over the last year, as well as development threats to the area. In this way, local people are acting as our ‘surveyors’. We record detection for a sampling unit if any of the following are successfully established: direct sighting of the animal (alive or recently killed), direct observation of sign (tracks, burrows, or vocalizations), and in the case of jaguars, direct observation of a jaguar kill.

We treat each interview as a separate replicate for the computation of detection probabilities. Six interviews are conducted per sampling unit providing a detection/non-detection matrix for the study area. Because we cannot meet certain assumptions to estimate true occupancy, we interpret the occupancy parameter as ‘proportion of area used’. This is sufficient to meet the goals of our corridor assessment efforts since we are more interested in use of an area than occupation.

For each corridor, we model habitat use and detection probabilities as a function of covariates. Habitat covariates may include proportion of forest, grassland, agriculture/shrub, open areas, early-stage forest re-growth, wetland, and water. Topographic and anthropogenic covariates may include mean elevation of a sampling unit, and distance to roads, settlements, and protected areas. Interviewee-specific covariates may include length of residency, survey effort, mode of transportation, and reason for visitation to a sampling unit.

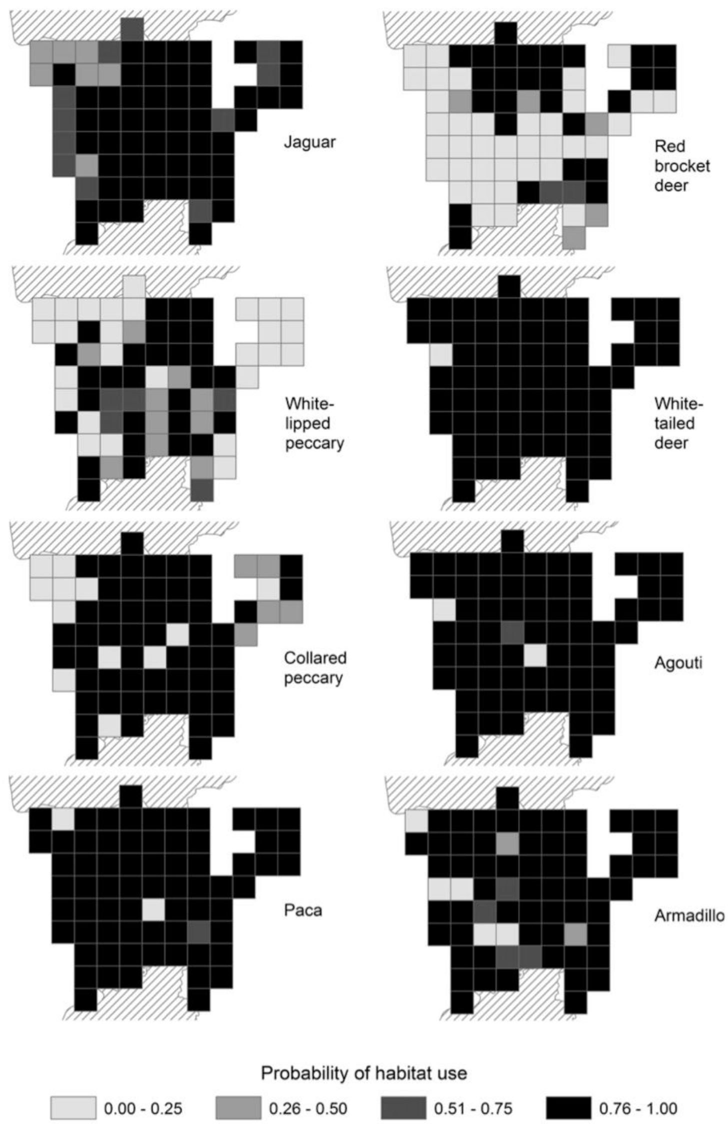

Figure 3. Probability of habitat use of jaguar and 7 prey species in a corridor area in Nicaragua (from Zeller et al. 2011). Probabilities were obtained from an occupancy model that used data collected from interviews with local residents.

Models are ranked using the small-sample correction to Akaike's Information Criterion (AICc). Whenever there are a number of candidate models with relevant covariates and with similar AIC weights, we apply a model averaging technique to estimate probabilities of habitat use and detection (Buckland et al. 1997; Burnham & Anderson 2002). An example of the resultant probabilities of habitat use of our target species is provided in Figure 3.

The probabilities of habitat use are used to identify the most appropriate corridor between two JCUs. For example, in a corridor area in Nicaragua, a sampling unit qualified for corridor inclusion if it had greater than 75% probability of use by all the smaller prey species and by at least two of the larger prey species and greater than 90% probability of jaguar use (Figure 4) (Zeller et al. 2011).

We recognize the thresholds on probability of habitat use by prey and jaguar for corridor inclusion are slightly arbitrary. However, in the absence of genetic data documenting movement and breeding between populations, use of the area by the target species for which the corridor is intended is one of the best signs of functional connectivity (Hilty et al. 2006; Noss & Daly 2006). Also, high probability of presence of a variety of natural prey species of different sizes further indicates a relatively healthy corridor.

Data from the field assessment of the corridors can be used to promote corridor conservation and inform management decisions because they present a strong argument, backed by scientific data, for a jaguar corridor. The resultant maps can also be used as the foundation from which future corridor implementation can be based and against which future conservation strategies can be measured.

For example, Figure 4 shows how targeted restoration efforts in a few non-qualifying sampling units in the southwestern part of this study area might result in widening the corridor and making connectivity through this area more robust. Pair this with interviewee reported data on development threats and a strategy for effective conservation action becomes clear.

5. Conservation Efforts

The identification of appropriate areas for range-wide jaguar conservation, and the subsequent prioritization and field assessment, provide a strong basis for building long-term, site-based conservation strategies. Effective conservation depends on a variety of factors that satisfy local and regional human needs and that fit into the often diverse cultural contexts of these communities.

In order to meet such needs, we have developed a multi-faceted approach to conservation. In addition, we seek conservation applications that can be sustainable; benefiting not only long-term jaguar conservation, but also local communities.

To get a birds-eye view of the current conservation status of the JCI, we overlaid the 2010 World Database on Protected Areas (WDPA) on the JCUs and corridors. We found that 1.28 million km^2 of the JCUs (67%) and 1.2 million km^2 of the corridors (46%) were under some form of protection.

The WDPA includes all protected areas, from strict national parks to multiple use areas and the level of protection of the JCI varies widely, however over the whole JCI, 55% is already managed with some level of protection (Figure 5).

By no means can we ignore this 55%, but the protected areas do provide a ready platform from which conservation action can take place (see section *5.1* and *5.4.3.*). For the other 45% of the JCI, there are very few established programs for conservation. From the spectrum of lands that range from strictly protected to unprotected, conservation across Latin America must take many forms and target many levels, from the highest government officials, to the local landowners.

In the following sections, we describe some of the conservation options available to jaguar conservation practitioners across these different levels of engagement, and provide some examples from our experience in the field.

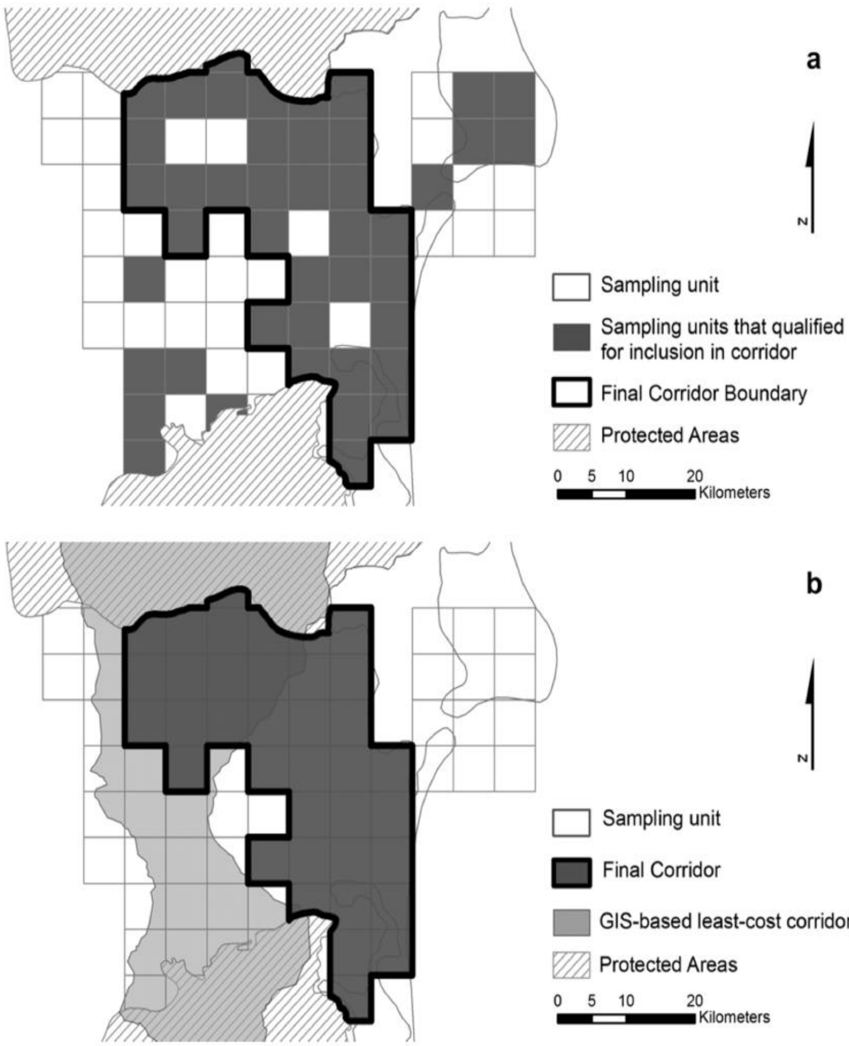

Figure 4. Sampling units qualifying for corridor inclusion and comparison to least-cost corridor (from Zeller et al. 2011).

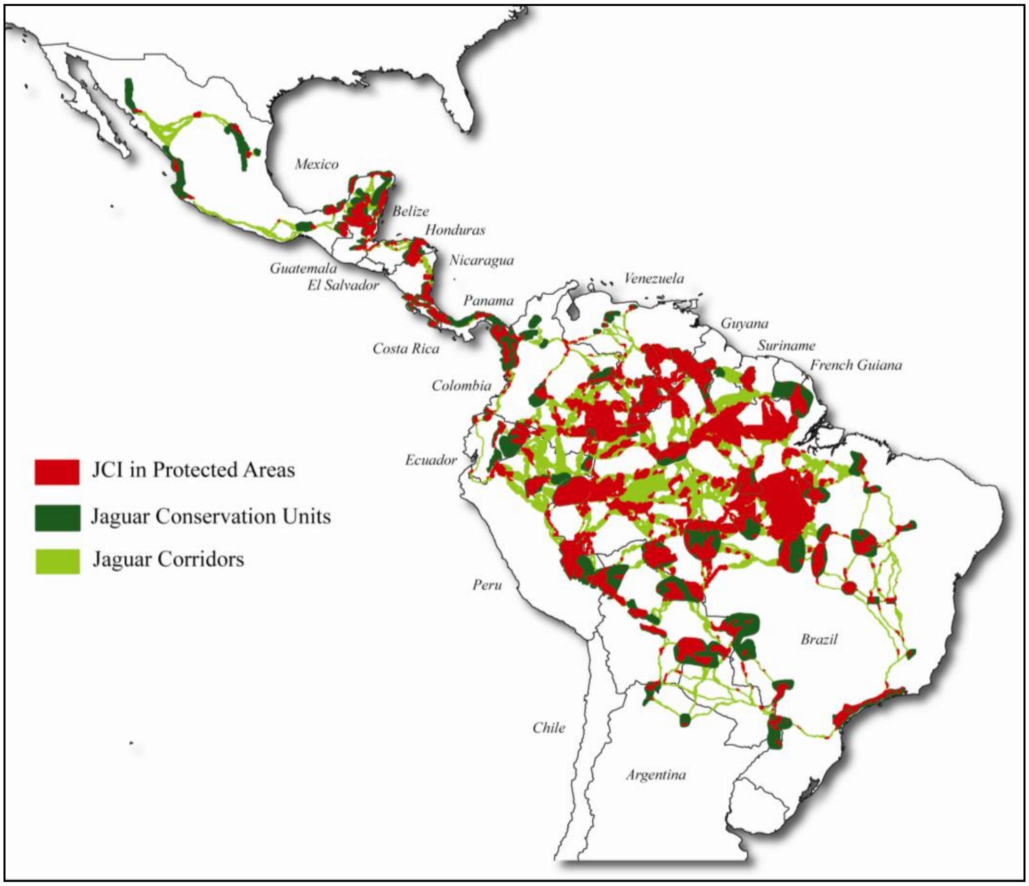

Figure 5. Areas of JCUs and corridors under protected status.

5.1. Land Tenure Analyses

Conservation must be tailored to the unique threats, opportunities and composition of each individual JCU and corridor. Thus, one of the first, and essential, activities for a jaguar conservation initiative is obtaining or creating a map of land ownership and land use.

Land tenure analysis requires a combination of public records access and on-the-ground evaluations. Public records provide ownership information, normally associated with a defined section of land. Within the public record, land parcels are identified with the person or agency of record. Land can either be owned by private citizens, or overseen and managed by municipal, state, or federal agencies. For conservation efforts, a record of ownership or management oversight, with contact information, allows for direct engagement with people and agencies that hold authority over those lands. Equally important is an assessment of the land use for each parcel. This is best performed using a combination of on-the-ground data, remotely sensed imagery, and governmental records. The latter is driven by the fact that many human activities require permits and annual reports. It is also helpful to know the level of human use, such as production per acre; this can provide a relative assessment of the intensity of land use.

5.2. National Policy Agreements and Legislation

Policy statements, agreed to and accepted by government entities, are perhaps the most powerful conservation tools for implementing conservation efforts. These tools are commonly ignored by wildlife conservation practitioners, who are often unacquainted with working with government agencies and policy makers. However, formal agreements with government entities, with joint acknowledgment of priorities, can provide important credibility and entry to conservation arenas that would normally be much more difficult in which to work. In addition, these agreements can make government involvement, and even ownership, of the conservation objective – in this case, the JCI – more sustainable in the long-term.

Our experience involves the development of ties to upper levels of government, often at the ministerial level. Such ties have been used to promote agreements and initiate fieldwork on the JCI framework. The JCI, as a science based, landscape framework, focused on an iconic species, may provide a more attractive target for government buy-in than other conservation activities. This may be especially true in Mesoamerica, where a regional biological corridor has been agreed to by the ministers of seven countries. In all regions of the JCI, the current ecological value placed on connectivity has also assisted the acceptance of the jaguar corridor at upper governmental levels.

From a practical standpoint, our written agreements have normally been developed in the form of a “memorandum of understanding” or a “letter of agreement.” Such agreements, at their most basic, acknowledge the importance of the jaguar and the need to preserve it and maintain the species’ connectivity. Such simple documents provide strong background and support for activities on the ground, and for cooperation with private citizens, local governments, and government agencies. In their more evolved form, these agreements can set a framework for government financial commitments, the establishment of personnel within government that function to promote jaguar conservation efforts, and provide for legislative frameworks to seek conservation support for particular areas or particular activities. For instance, agencies might commit to jaguar conflict mitigation personnel; legislatures might commit to tax incentives for the maintenance of forest habitats within defined corridor areas. The potential for these agreements to provide long-term and short-term impacts on jaguar conservation cannot be overstated.

5.3. District and Municipal Level Partnerships

Collaboration and commitment from the local governments in the JCUs and corridors can be as important as the commitments at the national level described above. Local leaders and politicians may have the power to make decisions on local issues such as development projects, large-scale investments, urbanization of areas, and protection of natural resources. Furthermore, support at the national level does not always trickle down to the local governments, especially when the two are of different political parties.

Environmental issues in rural and poor areas (that unsurprisingly coincide with the most important areas for the jaguar) are often not prioritized on the local government’s agenda. Land development, the building and enhancement of roads and bridges, and improvement of health and sanitation conditions are generally prioritized over management of wildlife and natural resources. Furthermore, development decisions are usually made without considering the negative impacts they may have on the environment. The frequent absence of a strategic development plan for an area, the short tenure of local political offices, and the pressure to have immediate answers for their constituents, frequently makes the district and municipal leaders favor environmentally destructive projects that promise employment and other monetary benefits. Possible negative impacts, such as the loss of the equilibrium of the ecosystem, the loss a species of cultural importance, the dramatic changes over the way of living of the people, the disruption of clean sources of water and food, are seldom addressed.

Even so, on several occasions, we found that local government leaders are not opposed to listening to environmental issues. Once provided with an explanation and sound data on the importance of preserving certain natural areas or with real alternatives to a destructive project, they have the tools to make informed decisions and will often take action to aid wildlife or the environment. In fact, several municipalities or "Alcaldias" have a person, or even a whole committee to oversee environmental issues, but they lack the proper knowledge, resources, data, or support, to effectively communicate to the decision makers.

Panthera, through collaboration with local corridor councils (see section *5.4*), is providing scientific data to local governments to aid in their decision making. For example, we are establishing base-line information on the presence of jaguars, other cats and their prey, information on habitat quality and availability, land use/land cover data, and information on the location of core areas of connectivity. We have also provided guidance on road building, locations for environmental mitigation projects, and municipal land use plans to ensure preservation of, and contiguity of, habitat for jaguars and their prey. And, lastly, we have alerted local governments to possible threats to important water and forest resources so appropriate action could be taken.

Relationships built at the municipal level must be continually maintained, as politicians, committees, and threats are constantly evolving.

5.4. Landowners, Local Businesses, Protected Areas, and Indigenous Groups

Although political support is essential to guarantee the goal of conserving jaguars throughout their range, conservation objectives will fail unless they are supported and upheld by the local residents. Therefore, projects oriented toward the preservation of wildlife and natural resources should incorporate, at their core, the people that live and work in these areas. This is especially true for the corridor areas, where the majority of the land is privately owned. Not only should these players be incorporated into the equation, but also they should eventually feel ownership of the project. Too many times, local and foreign NGOs have tried to import ready-made conservation projects that, for various reasons, are not successful, or are only successful while the NGO remains a presence in the area.

Maintaining support for jaguar and environmental issues is not any easy task since many important jaguar areas are located where the people have very few economic opportunities. It is not surprising when local people welcome open-pit mines, intensive forestry projects, large mono-culture plantings, or hydroelectric dams in exchange for short-term economic benefits. Although the costs of these projects frequently have a high toll on the ecosystem in general, these are considered as common resources and, thus, are rarely appreciated for the real value that they have, especially in the long-term (Hardin 1968).

The idea, therefore, is to engage local residents in conservation issues so that they feel ownership and pride in their natural resources and to create alternatives to potentially destructive development projects – ones that are not only environmentally sustainable, but are actively sought. The following sections describe actions and partnerships we have formed to achieve these goals.

5.4.1. Local Corridor Councils

During the field assessment of a corridor, local groups, businesses, and landowners are identified. These may include, but are not limited to, community based development groups, local indigenous governments, environmental groups, farmer associations, protected area personnel or support committees, natural resources protection groups, teachers, local leaders, private landowners, tourism enterprises, universities, large corporations (see below), and local government entities (municipalities or "alcaldias", ministry in charge of natural resources, ministry in charge of agriculture and ranching, ministry of health, ministry or institute of tourism, ministry of culture, etc.). These entities are approached to gauge their interest in being a member of a local corridor council.

Local corridor councils typically meet once a month. In the beginning, it is helpful to go through exercises that draw out personal concerns and needs of the members. It is also essential to do a formal assessment of the corridor where strengths and opportunities are identified to address threats. This assessment forms the basis of the local corridor council's action plan and lays out a clear road map for local actions in response to current and impending threats. It also allows members to express their concerns and feel empowered by being part of the process. It stands to mention that even though jaguar conservation may not be the main objective of the members, there is no doubt that the action plan developed – whether it addresses how to increase tourism that is dependent on a particular species, like the green macaw, or how to maintain water resources by conserving headwater forests – will have a positive influence on the preservation of the jaguar. A broad approach, with the support of a wide array of groups, results in a larger impact than a single organization fighting to save a species without considering the local needs, partners, and priorities.

Furthermore, the survival of the local corridor councils depends on the conviction and dedication of each individual member. This is especially true given that the great majority of participants in these corridor committees do so "*ad honorem,*" by investing their own time or integrating the corridor objectives as part of their work. Willingness to serve on a local corridor council is enhanced if there is some perceived benefit, and casting a wider net will attract more members.

For example, a group of dairy farmers in one of our corridors in Costa Rica were part of the local corridor council. They expressed concern about livestock depredation and some admitted their only recourse was to kill jaguars. We helped them establish a working group and provided livestock management techniques that not only offered solutions for the cat-cattle conflict in the area, but also increased yields and profits. To this day, this group of farmers is working on establishing a cooperative from funds they have received from writing proposals. The cooperative is further supported by two universities, at least four different government organizations, one private company and two NGOs. More information on rancher outreach and mitigation is provided below.

One of the main advantages of biological corridor councils is that they provide a platform to coordinate actions and projects between an array of groups and people that would otherwise be very difficult. This not only guarantees quick actions, but also increases the possibility of making the greatest impact with the resources available.

Costa Rica and Panama have established Biological Corridor Programs within their respective ministries of natural resources. This provides a platform for creating corridor councils (SINAC 2007, SINAC 2008, SINAC 2009) and helps to integrate action plans with other government programs. In other countries within jaguar range, corridor programs do not exist at the national level; however the creation of corridor councils can easily be emulated.

5.4.2. Rancher Outreach and Mitigation

For jaguar conservation, one of the most important human activities in jaguar range is cattle ranching, and livestock production generally. It can degrade jaguar habitat, especially with intensive pasture expansion and maintenance in the various types of humid forest areas. But, it is also possible to maintain jaguar habitat, and healthy jaguar populations, in conjunction with cattle raising (Hoogesteijn & Hoogesteijn 2008, 2010a), especially in flooded forested savannas, and also through the planting of pasture, interspersed with native trees and shrubs in non- or less flooded areas (Hoogesteijn et al. 2010b) that can provide habitat for jaguars and for their native prey. However, the other side of this conservation imperative is the direct killing of jaguars in retaliation for their killing of livestock. This activity permeates jaguar range, and it would be a difficult challenge to seek answers range-wide (each country and each ecological unit in each country face different problems and different solutions). However, through a long-term program of testing and applying specific actions, we have been able to devise recommendations for cattle raising that are proven to reduce jaguar depredation and increase herd productivity (Marchini & Luciano 2009; Hoogesteijn & Hoogesteijn 2008, 2010a, 2011).

Our focus to date has been to broadcast these methods through workshops and media. Our second phase, currently being initiated, is to continue the research and applications, advancing the methodologies, but to focus directly on ranches within the defined jaguar corridor. This approach provides a more strategic application to specific areas of need and provides direct examples of success that the neighbors to these ranches will, hopefully, observe and emulate.

5.4.3. Participation in Protected Area Development and Management

Panthera is also involved in supporting the protected areas throughout the JCI to maintain or increase their efficacy. We are involved in helping protected areas develop their management plans (*e.g.* Barbilla National Park, Costa Rica), providing support for park ranger patrols (*e.g.* Jeannette Kawas National Park, Honduras), promoting new protected areas (*e.g.* Labouring Creek Jaguar Corridor Wildlife Sanctuary, Belize), helping resolve conflicts with local communities (*e.g.* Maquenque Mixed Wildlife Refuge, Costa Rica) and data collection on jaguars and prey (in several areas in throughout the region).

5.4.4. Indigenous Groups

One group that deserves a section of their own is the indigenous community. The JCI passes through many indigenous territories – most likely due to the presence of large tracts of forest, limited access, and lack of intensive development. Though provided with autonomy in many countries throughout jaguar range, some indigenous communities lack land use planning guidelines or a framework for managing their natural resources. To address this and prevent haphazard development and habitat fragmentation, Panthera, along with other NGOs and biological corridor councils have been promoting land use planning and resource management strategies through training and helping these communities gain access to conservation funds.

5.5. Large Scale Development and Collaboration with Corporations

As we have previously stated, investment and development are always welcomed in deprived areas, sometimes at a very high cost to the environment. By no means is Panthera opposed to improving the conditions for people that live in or near the areas that are important for jaguars. In fact, in the corridors, an orchard or other agriculture type that provides some vegetative cover, might serve as an area through which jaguars would be willing to move. The key is in finding the middle ground, where certain large projects may be able to incorporate environmentally beneficial practices while not compromising on economic gain. This may seem an idealized notion, however, more often than not, establishing an open door of communication helps in producing a positive outcome.

This is, in fact, our first step in working with large corporate interests. We approach the local affiliates of the corporation with information about the corridor, show them the importance of their lands within the JCI, and have a discussion about their work and possible options. Sharing information and being transparent in our intentions is key to a successful meeting.

One of the most common examples of potential barriers to dispersing animals is the improvement and building of roads. Examples of these occur in the northern coast of Honduras where there is a plan to increase the number of lanes to create a “dry canal” between the Atlantic and the Pacific. We also have ongoing projects in Costa Rica and Colombia where we are identifying crossing routes and providing advice on how to promote the safe passage of these animals using tunnels, bridges, speed bumps and informative signs, to name but a few.

Another example of opportunities for working with corporations is with large scale agriculture such as African palm plantations. This is especially true in northern Honduras and the Southern Atlantic Autonomous Region in Nicaragua, where the only possible passage across a section of corridor is through these plantations. We are working with corporations and university students to study the effects of African palm on jaguar movement and prey populations. We are particularly interested in the differences between plantations of different sizes and at different growth stages, and in comparing plantations with undergrowth with those that have no understory vegetation. The ultimate goal is to determine if there are management strategies corporations can implement that would reduce the negative impacts to wildlife in the areas in which they work.

We have also found an opportunity for collaboration with a major hydro-electric company in one of our corridors in Costa Rica. Through our local corridor council, we have established close communication with the company. The company is required to perform mitigation measures to counter the negative impacts of the dam. We are providing guidance for the selection of lands for environmental mitigation. Without input on the wildlife connectivity in the region, the prioritization of land for acquisition would likely have been haphazard. We are recommending the acquisition and restoration of lands that promote the continuity of forest cover around the end of the reservoir. We are also freely sharing relevant GIS data to aid them in this process. Lastly, we are collecting baseline information on jaguars and prey in the area to document the before and after effects of the reservoir.

6. MONITORING

Because the JCI is a fairly young initiative, we are still the first phase of gathering field data, identifying conservation action plans, and implementing the beginnings of those plans. We do plan to monitor the JCUs and corridors to determine, 1) if our conservation actions are working, and 2) to identify any emerging threats to the JCI so that conservation plans can be adjusted accordingly.

We are just developing our monitoring protocol, so we are unable to provide a detailed methodology at the moment. However, we plan to monitor both JCUs and corridors every 5 years by using a combination of remote sensing data and field data.

We will use remotely sensed data to perform a land cover change analysis. Areas of forest conversion will be highlighted and we will be able to determine whether we are meeting our habitat goals and if any large new incursions have occurred.

We will collect field data in the JCUs in order to obtain density estimates for jaguars and relative abundance indices for prey to determine if the populations are remaining stable, declining, or increasing. For the corridors, we will collect detection/non-detection data to determine if the probability of presence of jaguars and prey has remained stable, is declining, or increasing.

The results of the monitoring will likely highlight new threats and needed changes to the conservation approaches of these areas. The action plans will be adapted as needed.

CONCLUSION

The JCI, measuring 4.5 million km^2, is the largest conservation network in the world. Based on core breeding populations and corridors connecting these populations, the JCI seeks to conserve all the biological and ecological attributes of the species so that, even in the face of expanding development, the jaguar will persist long into the future.

The JCI is unique from other range-wide priority setting exercises, not just because of the incorporation of corridors. We obtain field data on jaguar populations and corridors to increase the level of accuracy of the RWPS and bolster our database with empirical information. This, in turn, provides a baseline of data from which monitoring can take place, and allows for the assessment of threats and the identification of conservation opportunities.

JCUs are the heart of the network and are crucial for maintaining jaguar numbers. Experts from throughout jaguar range provided information to identify these core populations and the state of these populations. However much of the information provided was a best guess and was not based on empirical information. We are currently assessing 2 of these JCUs to obtain empirical data on jaguars and their prey and to do a thorough ‘threats assessment.’ Once we have refined the protocol, we will expand the assessments to more priority JCUs across jaguar range. Once a JCU assessment has been completed, a conservation action plan will be implemented for that population.

Corridors provide for the long-term genetic viability of the jaguar by providing dispersal routes between populations, and preventing extensive habitat fragmentation and isolation of populations. The results of the corridor analysis echoed the findings of the genetic studies (Eizirik et al. 2001; Ruiz-Garcia et al. 2006) in that no significant breaks were found in the corridor (with the exception of north eastern Honduras, likely due to recent land cover change). The field assessment of the corridors is providing vital information about the use of these areas by jaguar and their prey and the threats jaguars face outside of protected areas. To date, we have assessed over 20,000 km^2 in 11 corridors throughout Central America. Data from 1,868 interviews have been collected and 1,299 sightings of jaguars (or evidence of) have been reported in the corridors.

Backing up the JCUs and corridors with empirical data provides us with the information needed to approach national, regional, and local entities regarding jaguar conservation. Armed with this data, the fact that jaguars and prey are present in these areas cannot be ignored. In addition, the efforts made to collect the data portray a message of gravity and commitment to the cause.

The extent of the JCI necessitates a myriad of conservation approaches across all levels of public and private entities. And, for each specific area a different suite of conservation techniques will likely be used. Politicians will differ, communities and their needs will differ, and the landscape will differ. Therefore, no conservation effort can be neatly described nor can a packaged approach be applied.

Conservation of this type requires the ability to come to each area with an open mind, listen, adapt and problem solve. Admittedly, at the start of this initiative, we did not foresee having meetings with oil palm plantation operators and mine owners. However, we have learned that in every threat may lie a conservation opportunity and that no entity in an area, large or small, should be discounted. Furthermore, we did not expect to receive so many reports of jaguars within human-dominated corridor areas and changed our conservation approach from simply maintaining minimum habitat requirements for dispersal to including rancher outreach and mitigation, education, and working with local people towards acceptance of the jaguar.

None of the work described in this chapter could have been accomplished without dedicated and passionate partners. The JCI is so immense, its success depends upon the conservation community working together toward this common goal. Our intention was to present a clear, scientifically-supported framework for a range-wide jaguar conservation strategy with concrete examples of on-the-ground action.

We hope regional scientists and conservation practitioners will adopt this strategy and that transparent and engaging collaborative projects will pave the future of jaguar conservation. We must take preemptive action to prevent the jaguar from going the way of the tiger so that ecosystems and future generations can benefit from the presence of this great cat. We cannot do this with individual projects scattered across the range. We must pool resources and join forces – not only to save the jaguar, but the ecosystems in which they are a part.

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