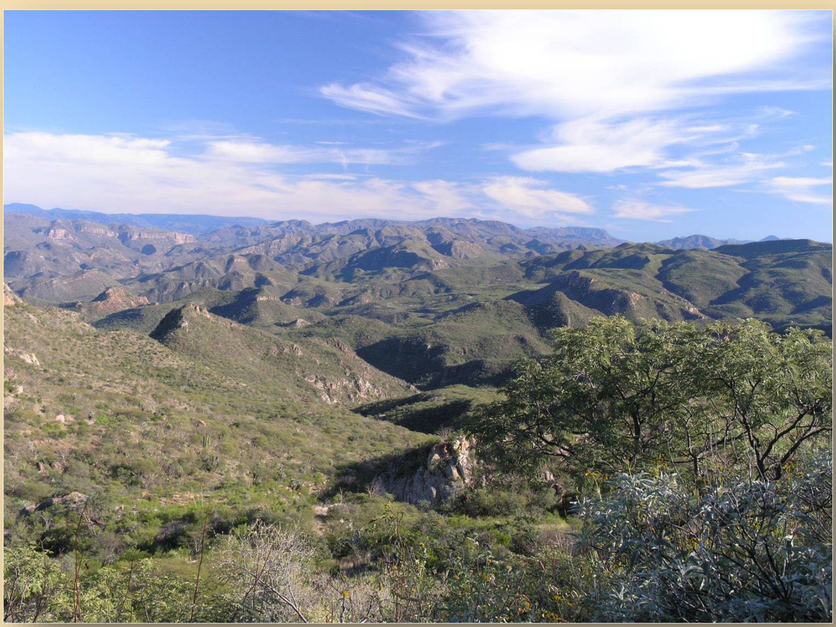
Northern Jaguar
Population and Habitat Viability Assessment

March 2011

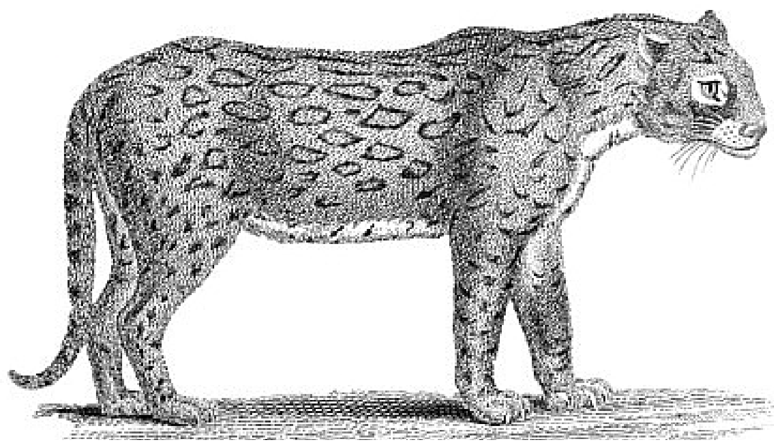


Final
Workshop
Report

Northern Jaguar (*Panthera onca*)
Population and Habitat Viability Assessment

1 – 4 March, 2011
The Rex Ranch
Amado, Arizona, United States

FINAL WORKSHOP REPORT



Workshop Organization:
Jaguar Recovery Team,
United States Fish and Wildlife Service

Workshop Design and Facilitation:
IUCN / SSC Conservation Breeding Specialist Group

Workshop Support:
United States Fish and Wildlife Service,
Northern Jaguar Project

Photos courtesy of Erin Fernandez, US Fish and Wildlife Service and Carlos López González, University of Querétaro.

A contribution of the IUCN/SSC Conservation Breeding Specialist Group, in collaboration with the United States Fish and Wildlife Service and the Northern Jaguar Project.

Fernandez, E., H. Quigley, C. López González, E. Sanderson, K. Fisher, P. Beier, T. Johnson, L. Carrillo and P. Miller (eds.) 2011. *Northern Jaguar* (Panthera onca) *Population and Habitat Viability Assessment: Final Workshop Report.* IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Additional copies of *Northern Jaguar* (Panthera onca) *Recovery Planning Workshop: Draft Report* can be ordered through the IUCN/SSC Conservation Breeding Specialist Group, 12101 Johnny Cake Ridge Road, Apple Valley, MN 55124, USA www.cbsg.org.

The CBSG Conservation Council

These generous contributors make the work of CBSG possible

$50,000 and above

Chicago Zoological Society
-Chairman Sponsor

$20,000 and above

Minnesota Zoological Garden
-Office Sponsor
Omaha's Henry Doorly Zoo
Saint Louis Zoo
Toronto Zoo
Zoological Society of London

$15,000 and above

Columbus Zoo & Aquarium - The WILDS
Disney's Animal Kingdom
SeaWorld Parks & Entertainment
Wildlife Conservation Society
World Association of Zoos and Aquariums (WAZA)

$10,000 and above

San Diego Zoo Global

$5,000 and above

Al Ain Wildlife Park & Resort
British and Irish Association of Zoos and Aquariums (BIAZA)
Chester Zoo
Cleveland Metroparks Zoo
Evenson Design Group
Linda Malek
Point Defiance Zoo & Aquarium
Sedgwick County Zoo
Toledo Zoo

$2,000 and above

Allwetterzoo Münster
Auckland Zoological Park
Bristol Zoo Gardens
Copenhagen Zoo
Dallas Zoo
Dickerson Park Zoo
Gladys Porter Zoo
Hong Kong Zoological & Botanical Gardens
Japanese Association of Zoos & Aquariums (JAZA)
Marwell Wildlife
Milwaukee County Zoo
North Carolina Zoological Park
Paignton Zoo
Phoenix Zoo
Royal Zoological Society of Antwerp
Schönbrunner Tiergarten – Zoo Vienna
Taronga Conservation Society Australia
Twycross Zoo
Union of German Zoo Directors (VDZ)
Wassenaar Wildlife Breeding Centre
Wilhelma Zoo
Zoo & Aquarium Association
Zoo Zürich
Zoologischer Garten Köln

$1,000 and above

Aalborg Zoo
Akron Zoological Park
Audubon Zoo
Central Zoo Authority, India
Colchester Zoo
Conservatoire pour la Protection des Primates
Cotswold Wildlife Park
Detroit Zoological Society
Everland Zoological Gardens
Fort Wayne Children's Zoo
Fota Wildlife Park
Givskud Zoo
International Animal Exchange, Inc.
Kansas City Zoo
Laurie Bingaman Lackey
Los Angeles Zoo
Nordens Ark
Ocean Park Conservation Foundation
Palm Beach Zoo at Dreher Park
Parco Natura Viva – Garda Zoological Park
Perth Zoo
Philadelphia Zoo
Pittsburgh Zoo & PPG Aquarium
Prudence P. Perry
Ringling Bros., Barnum & Bailey
Rotterdam Zoo
Royal Zoological Society of Scotland – Edinburgh Zoo
Saitama Children's Zoo
San Antonio Zoo
Seoul Zoo
Swedish Association of Zoological Parks & Aquaria (SAZA)
Taipei Zoo
The Living Desert
Thrigby Hall Wildlife Gardens
Woodland Park Zoo
Zoo Frankfurt
Zoo Madrid – Parques Reunidos
Zoological Society of Wales – Welsh Mountain Zoo
Zoologischer Garten Rostock
Zoos South Australia

$500 and above

Banham Zoo
Brandywine Zoo
Cincinnati Zoo & Botanical Garden
Edward & Marie Plotka
Friends of the Rosamond Gifford Zoo
GaiaPark – Kerkrade Zoo
Jacksonville Zoo & Gardens
Katey & Mike Pelican
Knuthenborg Park & Safari
Lisbon Zoo
Little Rock Zoo
Odense Zoo
Oregon Zoo
Ouwehands Dierenpark
Riverbanks Zoo & Garden
Wellington Zoo
Wildlife World Zoo & Aquarium
Zoo de la Palmyre

$250 and above

Alice Springs Desert Park
Apenheul Primate Park
Arizona-Sonora Desert Museum
Bramble Park Zoo
David Traylor Zoo of Emporia
Ed Asper
International Centre for Birds of Prey
Lee Richardson Zoo
Lincoln Park Zoo
Mark Barone
Mohawk Fine Papers
Racine Zoological Gardens
Roger Williams Park Zoo
Rolling Hills Wildlife Adventure
Sacramento Zoo
Tautphaus Park Zoo
Tokyo Zoological Park Society

$100 and above

African Safari – France
Chahinkapa Zoo
Darmstadt Zoo
Elaine Douglass
Lion Country Safari
Miami Metrozoo
Safari de Peaugres
Steinhart Aquarium
Steven J. Olson
Touroparc – France

$50 and above

Alameda Park Zoo
Vicki Scheunemann
Stiftung Foundation for Tropical Nature & Species Conservation

$25 and above

JE Schwolow

31 March 2011

Northern Jaguar (*Panthera onca*)
Population and Habitat Viability Assessment

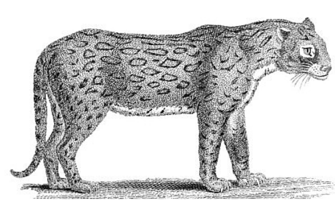
1 – 4 March, 2011
Amado, Arizona, United States

Contents

Northern Jaguar (*Panthera onca*)
Population and Habitat Viability Assessment

1 – 4 March, 2011
Amado, Arizona, United States

I
Executive Summary



Northern Jaguar (*Panthera onca*)
Population and Habitat Viability Assessment

Executive Summary

Introduction

The jaguar (*Panthera onca*) was first listed under the Endangered Species Conservation Act of 1969, and in 1997, was subsequently designated as an endangered species outside the United States under the Endangered Species Act of 1973(ESA). This protection was extended to jaguars in the United States in 1997. The U.S. Fish and Wildlife Service's (Service) Southwest Region has the lead for recovery of this species for purposes of ESA compliance. The jaguar was addressed in *Listed Cats of Texas and Arizona Recovery Plan (with Emphasis on the Ocelot)* (U.S. Fish and Wildlife Service 1990), but only general information and recommendations to assess jaguar status in the U.S. and Mexico, and protect and manage occupied and potential habitat in the U.S. were presented. No specific recovery criteria or actions for the jaguar were presented. As such, the Service is currently developing a recovery plan for the jaguar with emphasis on the species in the northern portion of its range. To initiate and inform this effort, the Service was interested in conducting a pair of workshops, a Population Viability Analysis (PVA) Workshop where detailed information on population dynamics and management options would be evaluated using computer simulation tools, and a Population Viability and Habitat Assessment (PVHA) Workshop for the northern jaguar, with members of the Service-led Binational Jaguar Recovery Team discussing the PVA results and their implications in the context of species recovery planning.

Specific goals of the Population Viability Analysis and Population Habitat and Viability Assessment included:

- To conduct a PVA with the Technical Subgroup of the Jaguar Recovery Team and summarize and utilize the results from it for use in the PHVA;
- To conduct a PHVA with the Technical and Implementation Subgroups of the Jaguar Recovery Team;
- To assemble as much information as possible on jaguars and jaguar conservation in the northern portion of their range;
- To identify the range of challenges to successful recovery of jaguars in the northern portion of the species' range (western and northwestern Mexico into the southwestern United States);
- To list long-term goals and shorter-term actions that will collectively facilitate jaguar recovery in the northern portion of its range;

The Conservation Breeding Specialist Group (CBSG), part of the Species Survival Commission of the IUCN – International Union for Conservation of Nature, was asked to provide expertise in PVA methodology and PHVA workshop design and facilitation.

The Workshop Process

CBSG's PVA and PHVA workshop processes provide an objective environment, expert knowledge, and neutral facilitation that support the sharing of information across institutions and stakeholder groups, fostering agreement on the issues and information, and enabling stakeholder groups to make useful and practical management recommendations for the taxon and habitat system under consideration. This approach has been quite successful in unearthing and integrating previously unpublished information that is frequently of great value to the decision making process. This interactive and participatory workshop approach supports and promotes effective conservation by fostering the creation of species management plans and the political and social support of the local people needed to implement these plans. In addition, PVA simulation modeling is an important tool in this process, and provides a platform for testing assumptions, data quality, and alternative management scenarios.

In anticipation of the PHVA Workshop, CBSG convened a PVA meeting in January 2011 to begin the process of developing a consensus dataset on jaguar biology and ecology, as well as a set of simulation models of jaguar population dynamics. During this preliminary meeting, biologists and GIS specialists from the Wildlife Conservation Society (WCS) began constructing a detailed database of historical jaguar sightings and event records, which was used in conjunction with simple habitat modeling tools to provide initial estimates of jaguar habitat associations and regional habitat suitability values. From this simple habitat model, preliminary estimates of jaguar carrying capacity could be proposed for various subunits of habitat stretching from west-central Mexico to southeastern Arizona and extreme southwestern New Mexico. These analyses provided valuable data and results that were to be a central focus of the March workshop.

The PHVA workshop began on 1 March 2011 at the Rex Ranch near Amado, Arizona, with approximately 35 participants in attendance, including members of both subgroups of the Jaguar Recovery Team, as well as some Service representatives. The participants were chosen to represent a broad diversity of stakeholders considered valuable to the species recovery planning process. Following opening remarks by Recovery Team Co-Leaders Howard Quigley and Carlos López González, participants were asked to identify those issues they believe are most crucial to the success of jaguar recovery in the northern part of the species' range. Selected participants gave a series of presentations on topics ranging from the regulatory framework of recovery planning to the status of jaguar populations and their conservation in northern Mexico and southwestern United States. Eric Sanderson and Kim Fisher of WCS summarized their habitat modeling work, and a summary of PVA work to date was provided by CBSG's Philip Miller. Workshop facilitator Luis Carrillo, of CBSG's Mexico Regional Network, then introduced the group to the overall workshop process and led a discussion from which three working groups emerged that would carry on parallel activities for the rest of the meeting: jaguar population viability analysis, human – jaguar interactions, and jaguar habitat management. All workshop participants were invited to choose which group they wanted to join. Through this process of self-selection, workshop participants were provided an opportunity to contribute their information and perspective in the most effective way.

In the afternoon of the workshop's first day, the working groups began moving through a set of structured tasks set forth by the facilitator. First, each group was asked to amplify those relevant issues identified earlier, to identify new challenges of importance to their specific topic, and to prioritize them according to an agreed criterion. The groups were then brought back to plenary, and each group shared their information and was able to provide commentary and perspective with their peers. This process of working group sessions, followed by discussions in plenary, continued throughout the workshop.

Once issues were identified and prioritized, the participants began to assemble information pertinent to their prioritized issues, in order to identify specific data sources, presumed assumptions, and obvious data gaps. This process element greatly enhances the subsequent identification of management and/or research priorities for the species, in the larger context of recovery.

Each working group then proposed, refined, and prioritized goal statements designed to address the prioritized issues identified previously. Following this process, the prioritized goals were brought to a plenary session where the goals were presented and discussed. The entire body of workshop participants was then asked to provide an overall sense of priority for these goals based on the importance of achieving them for successful recovery of the jaguar in their northern reaches of its range. This was accomplished by giving each participant a set of colored stickers and asking them to distribute those items amongst those goals they saw as most important to accomplish. Since these goals are directly tied to the issues identified earlier, the workshop design facilitates the resolution of stakeholders' needs in a clear and structured manner.

With goals in hand, each working group then began the task of identifying specific actions that would achieve those goals. These actions are included important details such as the individual responsible for moving the action forward, a timeline for completion of the strategy, important collaborators, and specific obstacles to overcome if the action is to be completed. With this level of detail, those actors and agencies responsible for species recovery have a valuable set of comprehensive recommendations to guide future management success.

Workshop Results

Habitat Modeling and Population Viability Analysis

Experts from WCS led the development of a database of relevant jaguar observations from historic times forward to the present, as well as a geographic information system (GIS) database of spatial data appropriate for mapping the jaguar's range and considering questions of its conservation and recovery. Using these data, a relatively simple habitat model was created for jaguars ranging from western Mexico to southwestern U.S. that was based on a modification of an existing model developed for jaguars in Arizona. Workshop participants developed a spatially explicit system of subunits within the Recovery Team's definition of an analysis unit that crosses the US / Mexico border (this analysis unit may be considered a "Recovery Unit", as described by the Service's Recovery Planning Guidance, for recovery planning purposes under the ESA).

These subunits correspond to subpopulations described in the set of metapopulation models developed by the working group. Best available information on jaguar biology and ecology was used to provide parameter estimates for a series of simulation models using the PVA software package *VORTEX*. Each simulation included estimates of demography specific to a given subpopulation unit, ranging from Jalisco in west-central Mexico to southern Arizona and New Mexico. Individuals were allowed to disperse among subpopulation units, thereby offering the opportunity to study metapopulation dynamics, including the conditions necessary for establishment of jaguar populations north and south of breeding populations in Jalisco and Sonora .

Analysis of these metapopulation models suggests that jaguar populations in the central and southern extent of the Northern Jaguar Population Analysis Unit – namely, those in Jalisco and southern/central Sonora – are of sufficient size to remain demographically viable as long as some level of dispersal acts to reduce the potentially deleterious effects that inbreeding depression may bring to a small and relatively isolated population. Moreover, this viability is critically dependent on at least minimal opportunities for population growth of key subpopulations in the absence of dispersal so that these areas can act as demographic source populations of dispersing individuals. The strength with which a source population can supply individuals for neighboring regions is critically dependent on its intrinsic capability for growth, itself a function of the threats imposed on it by local human activity. Establishment of a jaguar population in the United States is critically dependent on (i) a demographically robust core source population in Sonora, facilitating the dispersal of individuals both north and south; (ii) the ability of the habitat in northern Sonora to sustain jaguars in the long-term and to provide key dispersal corridors to the international border; and (iii) a permeable border between northern Sonora and the region of Arizona and New Mexico south of the I-10 highway corridor.

These insights, however, must be interpreted with caution as working group participants recognized the considerable uncertainty in our understanding of jaguar biology and ecology in this northern portion of the range. To address these considerable knowledge gaps, a number of recommendations were made to design studies that would increase our understanding of jaguar habitat use, population demographic characteristics, and metapopulation structure.

<u>Human – Jaguar Interaction</u>

Working group participants recognized the considerable divergence of opinions and perspectives among the many different stakeholders in this region with respect to jaguar perception, protection, and conservation. At a general level, stakeholders don't agree on goals for resource allocation, or on the methods for prioritizing them. More directly, participants identified the sometimes difficult association of jaguars and livestock in northern Mexico. Predation on livestock fosters negative attitudes toward jaguars, which significantly threatens the viability of management strategies that focus on creating conditions favorable for jaguar population expansion. At the international level, cooperation between the United States and Mexico in addressing issues of jaguar conflict and conservation planning is recognized as being poor, leading to slow progress in establishing wildlife population management activities.

To address these concerns, working group participants recommended the expansion of funding necessary to promote the most effective conservation activities on either side of the border. With greater financial capacity, it will be possible to coordinate meetings between government agencies, NGOs, landowners, and academics in each region to promote exchange of information, perspective, and philosophy which will provide a more secure basis for future conservation planning. In addition, a process must be adopted for integration of Mexican and American recovery planning documents so that both sides know where the international priorities are and what must be done to address them. These should also include other strategies and plans with translation of all documents into Spanish and English.

The group also recommends that direct killing (poaching) of jaguars should be reduced by 50% in the next few years, with similar reductions targeted at predation rates of jaguars on livestock. A critical component of this plan would involve more effective compensation programs for those ranchers that lose cattle to jaguar predation. Comprehensive environmental education programs for local citizens, in combination with programs designed to create economic incentives for jaguar conservation, are seen as vital elements of a long-term strategy for raising awareness and positive attitudes towards the species throughout northern Mexico.

<u>Jaguar Habitat Management</u>

Working group participants recognized that there is a general absence of effective jaguar habitat management on the ground, largely because of the uncertainty experts have on the details of jaguar habitat use and the factors influencing their dispersal dynamics. A major focus of study here could involve the dynamics of jaguar prey in determining jaguar habitat use, and the degree to which competition between jaguars and other predators such as pumas influence jaguar habitat use. In addition, there is a lack of information regarding the effects of human activities, including illegal and law enforcement activities, on jaguars, jaguar habitat use, and jaguar population dynamics and dispersal.

In addition to recommendations directed at improving landowner participation in jaguar conservation through the derivation of incentives, the working group developed a series of proposed research programs aimed at increasing our understanding of jaguar habitat use and the ways in which human-mediated activities threaten those natural processes. Specific studies would be designed to understand the competition for prey between jaguar and puma, and to understand how prey population dynamics influence associated jaguar population processes. Other studies would be directed at understanding how water availability and vegetation structure determine jaguar distribution and abundance, in accordance with predictions used for the simple habitat model developed by the PVA working group. Finally, studies were proposed to understand habitat/corridor needs of male and female jaguars, and to determine latitudinal trends in habitat use across the northern portion of the species' range.

The full breadth of goals developed by each working group can be found in each of the individual working group reports within this document. The plenary prioritization process discussed earlier revealed the following five goal statements as having top priority in a broad scheme of jaguar conservation in the northern portion of the species' range:

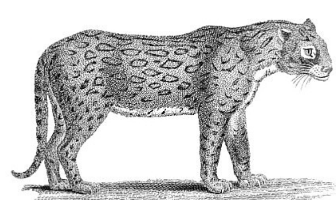
1. Develop secure funding sources that can be used on the either side of the border in focal areas that will generate the greatest conservation value.
2. Strengthen habitat conservation for jaguars.
3. Continue analysis of habitat use by jaguars and initiate more rigorous studies of jaguar habitat use in the northern part of the range.
   a. Identify habitat needs (parameters)
   b. Understand habitat needs
4. Continue and expand study sites to obtain more rigorous estimates of age and region-specific vital rates, including year to year variation in those rates (mortality, fecundity, etc.).
   a. Poaching/depredation rates
   b. Gender- specific dispersal rates and distances
5. Improve communication and collaboration among stakeholders.

By combining the use of rigorous scientific analysis of existing biological data with thoughtful and structured discussion of the needs of diverse stakeholder domains, this PHVA workshop is a valuable tool to initiate jaguar recovery planning efforts in west-central and northwestern Mexico and southwestern United States. Those involved in its organization and implementation hope that it will serve as a model for other jaguar planning efforts in other portions of its range, and for other species inhabiting the same geographic area.

Northern Jaguar (*Panthera onca*)
Population and Habitat Viability Assessment

1 – 4 March, 2011
Amado, Arizona, United States

II
Working Group Report :
Population Viability Analysis for the Northern Jaguar



Working Group Report:
Population Viability Analysis for the Northern Jaguar

Working Group Participants:
Paul Beier, Northern Arizona University
Erin Fernandez, US Fish and Wildlife Service
Kim Fisher, Wildlife Conservation Society
Carlos López González, University of Queratero
Phil Miller, Conservation Breeding Specialist Group
Howard Quigley, Panthera
Becky Raboy, Conservation Breeding Specialist Group
Eric Sanderson, Wildlife Conservation Society

Issues of Concern

1. We have uncertainty about the subunit boundaries on the current map.
2. We do not know what to call the focal area once it is delineated for the purposes of this workshop; a recovery or a management unit?
3. We have uncertainty about whether or not habitat suitability measures are as accurate as possible given available information.
4. We have insufficient data to justify habitat and subunit specific estimates of density and population demographics.
5. We have insufficient understanding of jaguar demographic and ecological parameters that would allow us to carry out the most accurate and meaningful PVA.
6. We don't understand how climate change may affect demographic and ecological parameters of importance to our PVA.

Baseline Input Parameters for Population Viability Simulation Models

Population viability analysis (PVA) can be an extremely useful tool for investigating current and future demographic dynamics of jaguar populations in the northern portion of the species' range. The need for and consequences of alternative management strategies can be modeled to suggest which practices may be the most effective in managing northern jaguar populations. *VORTEX*, a simulation software package written for PVA, was used here as a vehicle to study the interaction of a number of jaguar life history and population parameters, and to test the effects of selected management scenarios.

The *VORTEX* package is a simulation of the effects of a number of different natural and human-mediated forces – some, by definition, acting unpredictably from year to year – on the health and integrity of wildlife populations. *VORTEX* models population dynamics as discrete sequential events (e.g., births, deaths, sex ratios among offspring, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modeled as constants or random variables that follow specified distributions. The package simulates a population by recreating the essential series of events that describe the typical life cycles of sexually reproducing organisms.

PVA methodologies such as the *VORTEX* system are not intended to give absolute and accurate "answers" for what the future will bring for a given wildlife species or population. This limitation arises simply from two fundamental facts about the natural world: it is inherently unpredictable in its detailed behavior; and we will never fully understand its precise mechanics. Consequently, many researchers have cautioned against the exclusive use of absolute results from a PVA in order to promote specific management actions for threatened populations (e.g., Ludwig 1999; Beissinger and McCullough 2002; Reed et al. 2002; Ellner et al. 2002; Lotts et al. 2004). Instead, the true value of an analysis of this type lies in the assembly and critical analysis of the available information on the species and its ecology, and in the ability to compare the quantitative metrics of population performance that emerge from a suite of simulations, with each simulation representing a specific scenario and its inherent assumptions about the available data and a proposed method of population and/or landscape management. Interpretation of this type of output depends strongly upon our knowledge of jaguar biology, the environmental conditions affecting the species, and possible future changes in these conditions.

The *VORTEX* system for conducting population viability analysis is a flexible and accessible tool that can be adapted to a wide variety of species types and life histories as the situation warrants. The program has been used around the world in both teaching and research applications and is a trusted method for assisting in the definition of practical wildlife management methodologies. For a more detailed explanation of *VORTEX* and its use in population viability analysis, refer to Appendix I, Lacy (2000) and Miller and Lacy (2003).

Timestep for all simulations: Since jaguar reproductive ecology is easily described on an annual basis, we have chosen the timestep for our simulations as one year.

Metapopulation structure: For all analyses presented here, we identify a total of six subpopulations that collectively comprise the Northern Jaguar Population Analysis Unit. Note that the current boundaries of the Recovery Unit include only five subpopulations as shown in Figure 1; while the region north of I-10 is not considered to be part of the Recovery Unit, it has been included in our demographic analyses.

The working group participants then addressed the issue of whether the analysis unit is officially designated as a Recovery Unit or a Management Unit. A *Recovery Unit* is officially defined as “A Subunit of the listed species that is geographically or otherwise identifiable and is essential to recovery of the entire species”, while a *Management Unit* is defined as “A Subunit that is not necessarily essential for the recovery of the entire species”. US Fish and Wildlife guidance recommends that “when in doubt, designate as a management unit”.

Can the Northern Jaguar Population Analysis Unit be considered a Recovery Unit??

- Yes, in that it is identifiable, primarily in relation to the presence of xeric habitat; and
- Yes, it is essential for recovery of the species. (Although this statement depends on the language of the term “recovery”). The intent is to preserve jaguars across all of their unique ecological settings.

Based on this information presented above, the group recommends the official designation of the area as a Recovery Unit and drafted the following statement:

Figure 1. Final map of the subpopulation designations and Jaguar Conservation Unit (JCU) boundaries that emerged from discussions at the Northern Jaguar Recovery Planning workshop, March 2011.

Justification for Identifying the Recovery Unit as the Current Analysis Unit

Recovery units are subunits of the listed species that are geographically or otherwise identifiable and essential to the recovery of the species. Recovery units are individually necessary to conserve genetic robustness, demographic robustness, important life history stages, or some other feature necessary for long-term sustainability of the species.

> Establishing recovery units is a useful tool for species occurring across wide ranges with multiple populations, varying ecological pressures, or different threats in different parts of their range.
>
> The Northwestern Recovery Unit is a logical recovery unit because: 1) it encompasses the current known range of the putative subspecies (*Panthera onca arizonensis*); 2) it has distinct ecological conditions that occur nowhere else in the species' range (Sanderson et al., 2002); 3) peripheral populations such as these are important genetic resources; and 4) peripheral populations may be beneficial to the protection of evolutionary processes and the environmental systems that are likely to generate future evolutionary diversity (Lesica and Allendorf 1995). This may be particularly important considering the potential threats of global climate change.

The characteristics of dispersal, defined in *VORTEX* as the probability that an individual will move from subpopulation X to subpopulation Y in a given year, are a key factor in driving metapopulation dynamics. In general, we assume that dispersal in jaguars is strongly male-biased, with 90% of dispersing animals each year identified as males, on average, in our models. Furthermore, we assign dispersal capability only to those individuals that are two to three years old, i.e., those individuals leaving their natal ranges and seeking to establish new territories. We also assume that dispersal is not density dependent, and there is no cost (defined as increased risk of mortality) to dispersal.

Within Mexico, no physical barriers appear to be operating to limit jaguar dispersal. In contrast, the border fence separating Mexico and the southwestern United States – for our purposes, Arizona and New Mexico – acts as a potentially significant obstacle to jaguar movement along segments of its length. The border fence is made up of two distinct types of structures:

- Pedestrian fencing, placed in areas that receive heavy pedestrian traffic and are closely monitored by United States Border Patrol personnel. This fence tends to be a substantial vertical structure, often times a few meters tall, and can act as a major barrier to jaguar movement.
- Vehicle fencing, placed in areas that are more difficult to monitor and which receive less pedestrian traffic. Vehicle fence can often prohibit passage by cars and trucks, but can potentially be porous to animal movement in the absence of disturbance through human presence.

In areas that cannot be monitored and where vehicle traffic is impossible, such as mountainous and especially rugged terrain, there is no fence along the border. These fence-free areas can actually act as a type of funnel to increase local density of people looking to cross the border; the same phenomenon could act to increase local jaguar population densities along the border. While this may increase human – jaguar interactions, with the possibility of reduced jaguar dispersal across the border, the working group concluded that this would not be a significant deterrent to movement as animals could simply cross the border at a time or location that offers less human contact.

The I-10 corridor was seen by working group participants as the most significant barrier to northward dispersal of jaguars. In the absence of specific structures designed to facilitate animal movement across the highway, the density of vehicle traffic is thought to be high enough to deter most jaguars from crossing.

Taken together, this information allows us to assign a relative rate of dispersal to neighboring subpopulations comprising the metapopulation, assuming that dispersal among neighboring subpopulations in Mexico is given a unit annual rate of 1.0:

Sinaloa → North Sinaloa:	1.0
North Sinaloa → Sonora:	1.0
Sonora → North Sonora	1.0
North Sonora → South of I-10	0.8
South of I-10 → North of I-10	0.5

Under this assumption, an assigned dispersal rate within Mexico of 2.0% leads to a rate across the international border fence of 1.6% and a rate across the I-10 corridor of 1.0%. We assume that dispersal is symmetrical, i.e., southward dispersal rates are equal to those describing northward movement.

Finally, unless otherwise specified, we assume that demographic rates are equivalent across subpopulations.

Breeding system: Jaguars are known to display a polygynous breeding system, where a single male may mate with multiple females during a give year. This is simulated in *VORTEX* by allowing adult males to be sampled multiple times as mattes for the set of available females.

Age of first offspring: *VORTEX* considers the age of first reproduction as the age at which the first clutch of eggs is laid, not simply the onset of sexual maturity. We assume that females can breed at three years of age, while males can breed at four years. Males at four years become full grown and defend territory and can be reproductive. However, it's beneficial for males to become reproductive as soon as possible to help establish a territory. Males could be capable at two years of age, but three years may be a better estimate than four if they follow the pattern of other large cats. On the other hand, it could take a year for a male to settle into a new territory. This is not a particularly sensitive parameter, as the presence of just a few males will ensure a successful level of breeding among the full complement of females. We do not know any three-year-old female that has bred in the Sonoran JCU; despite the absence of such an observation, we maintain that three years is the best estimate for this parameter.

Maximum Age of Reproduction: In its simplest form, *VORTEX* assumes that animals can reproduce (at the normal rate) throughout their adult life. The oldest known female in the wild with kittens was observed in Sonora and was estimated at thirteen years old, based on dentition data. While this is set as the maximum age of reproduction, age-specific mortality rates may be set so that the probability of actually reaching this age is quite small.

Litters per year: We assume that an adult female will produce only one litter per year.

Maximum progeny per litter: We assume that four kittens can be born in a litter. This estimate is derived from data on captive animals observed, and we assume this potential can be realized in the wild.

Offspring sex ratio: Without data to the contrary, we assume that across the entire population, newborn individuals do not deviate from a 50:50 sex ratio.

% Adult Female Breeding: This describes the average proportion of females that reproduce in a year. Lions produce a little every other year, and this is also thought to be true for jaguars. This translates into an annual probability of breeding of 50% for each adult female.

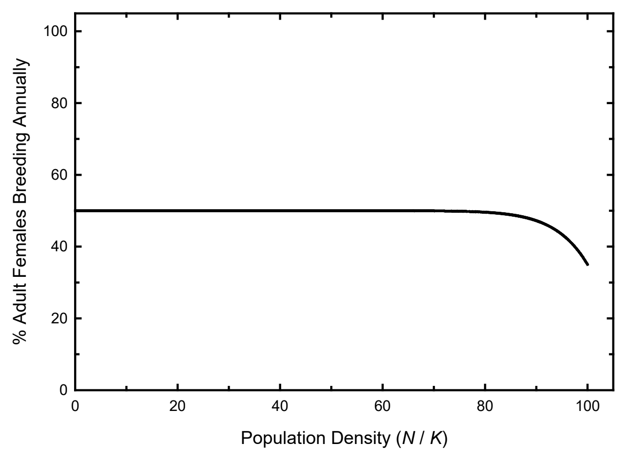
Density dependent reproduction: *VORTEX* can model density dependence with an equation that specifies the proportion of adult females that reproduce as a function of the total population size. In addition to including a more typical reduction in breeding in high-density populations, the user can also model an Allee effect: a decrease in the proportion of females that bread at low population density due, for example, to difficulty in finding mates that are widely dispersed across the landscape.

The equation that *VORTEX* uses to model density dependence is:

$$P(N) = \left(P(0) - \left[\left(P(0) - P(K)\right)\left(\frac{N}{K}\right)^{B}\right]\right)\frac{N}{N + A}$$

in which $P(N)$ is the percent of females that breed when the population size is N, $P(K)$ is the percent that breed when the population is at carrying capacity, and $P(0)$ is the percent breeding when the population is close to zero (in the absence of any Allee effect). The exponent B can be any positive number and determines the shape of the curve relating the percent breeding to population size, as the population becomes large. If $B = 1$, the percent breeding changes linearly with population size. If $B = 2$, $P(N)$ is a quadratic function of N. The parameter A defines the magnitude of the Allee effect.

We assume that there is a reduced frequency of successful breeding as jaguar populations approach maximum long-term equilibrium density (i.e., carrying capacity). If 50% of adult females successfully produce a litter at optimal densities, we assume here that only 35% of adult females are successful when the population is at carrying capacity. This reduction in breeding occurs only at rather high densities; this is reflected in a steepness parameter, B, in the density dependence equation equal to 16. Finally, Allee effects are assumed to be absent for this species. Taken together, these data result in a density dependence function of the form shown below, with % females breeding shown as a function of population density.



Environmental Variation (EV) in % Breeding: Annual environmental variation in female reproductive success is modeled in *VORTEX* by specifying a standard deviation (SD) for the proportion of adult females that successfully produce offspring in a given year. In the absence of specific data on this parameter, we assume that the variation is equal to 10%, thereby producing a full distribution of female breeding rates of 20% - 80% (mean±3SD). This is thought to be reasonable for variability in reproductive success for this species.

Distribution of Litter Size: The table below gives the probability of a given breeding female producing a little of the specified size. These values are based on expert judgment in the absence of specific field data for the species in the northern portion of its range.

Number of offspring	Probability (%)
1	45
2	45
3	5
4	5

The one exception to this specification is the North Sonora subpopulation, where the very low population abundance observed recently by López – González and others suggests some demographic factor limiting population growth. Specific data to explain this observation are lacking; expert judgment was used to suggest that reduced litter size is a primary factor. Therefore, we assume that in North Sonora 85% of adult females produce just one kitten per year and 15% produce two kittens.

Mate monopolization: In many species, some adult males may be socially restricted from breeding despite being physiologically capable. This can be modeled in *VORTEX* by specifying a portion of the total pool of adult males that may be considered "available" for breeding each year. We assume here that each 3-year-old male has an opportunity to breed, even wandering males without territories Therefore, we assume that 100% of the adult males have an opportunity to breed in a given year.

Mortality Rates: *VORTEX* defines mortality as the annual rate of age-specific death from year x to $x + 1$; in the language of life-table analysis, this is equivalent to $q(x)$. We assume that our model, intended to reflect the current Sonora population, will include the effects of human poaching in the age-specific mortality rates.

Very little quantitative data exist on population size trends for each of the subpopulations analyzed here. The best information comes from Sonora, where there is evidence to suggest that the population in the region studied by Carlos López – González is probably undergoing a slight decline in abundance over the period of observation in the past decade or, at best, remaining stable in numbers (neither growing nor declining). Therefore, we have back-calculated an age-specific mortality schedule that, when including the reproductive parameters discussed above, will lead to a trajectory in population abundance within *VORTEX* that recreates the observed trajectory over the period of the simulation. This schedule is given below.

	Mortality Rate (%) (SD)	
Age (years)	Female	Male
0 – 1	25 (6)	25 (6)
1 – 2	20 (4)	20 (7)
2 – 3	25 (5)	35 (9)
3 – 5	10 (3)	25 (5)
5 – 7	15.5 (3)	25 (5)
7 – 10	21 (3)	25 (5)
10+	26.5 (3)	25 (3)

Catastrophes: Catastrophes are singular environmental events that are outside the bounds of normal environmental variation affecting reproduction and/or survival. Natural catastrophes can be tornadoes, floods, droughts, disease, or similar events. These events are modeled in *VORTEX* by assigning an annual probability of occurrence and a pair of severity factors describing their impact on mortality (across all age-sex classes) and the proportion of females successfully breeding in a given year. These factors range from 0.0 (maximum or absolute effect) to 1.0 (no effect), and in its most basic implementation in *VORTEX*, are imposed during the single year of the catastrophe, after which time the demographic rates rebound to their baseline values.

There is as yet no consensus on the importance of including drought as an event in these models, but there is a suggestion that it be included as a modifier to mortality. This can arise from the fact that predation on cattle is more frequent during periods of drought, which could lead to high rates of jaguar poaching by ranchers. A "placeholder" has been included in the model for this event, but has not yet been activated.

Initial Population Size: Relatively little data exist on current abundance of jaguars in the region studied here. Based on survey estimates derived from recent efforts by Mexican government agencies, and recent research conducted in Sonora by López-González and in Sinaloa by Nuñez, we derived estimates of current population abundance for each of the regions under consideration. These are shown in the table below. Note that the North Sonora subpopulation is composed of males only as current research efforts have been unsuccessful in observing any females in the area. The estimate for North Sonora below is derived from observations of the number of jaguars observed in the area over the past 15 years.

Carrying capacity: How saturated is this population – is there an opportunity for the population to grow to a larger size? If poaching is a factor in our mortality schedule, we assume the population would increase if poaching pressure were relaxed. Estimates of carrying capacity for each subpopulation were derived using the habitat modeling approach carried out by Eric Sanderson and Kim Fisher (see Appendix A for a more detailed description of this approach). Data layers including vegetation, terrain roughness, distance to water, and exclusion of urban, rural and agricultural areas were used to produce a simple habitat model following a modification of the Hatten et al. (2005) method developed in concert with the Recovery Team. These continuous habitat variables were binned into discrete categories and then the distribution of events across the categories were examined to determine which categories were significant to jaguars. We then combined layers according to this equation:

Jaguar Potential Habitat Model =

([3-60% tree cover] + [intermediate, moderate, and high ruggedness]) (0-2) *
[Within 10km of water] (0-1) *
[HII >= 30] (0-1) *
[Potential habitat type weight] (0.1-2.5)

The Hatten et al. (2005) method was modified to include a weight according to potential habitat type, to represent the expert's sense of the suitability of different habitat types in terms of prey and cover. This weight represents the wider range of habitat types that occur over the study area. The resulting map (Figure 2) presents color-coded suitability, with darker colors indicating higher suitability values, and lighter colors indicating lower suitability.

Finally, the jaguar suitability map was rescaled to represent carrying capacity for jaguars by placing seven known adult jaguar density estimates from existing study areas, calculating the average suitability in those study areas, and then creating a regression between the habitat suitability scores and the density estimates, forcing the y-intercept of the regression through zero. From this, potential adult jaguar carrying capacities for each of the analysis unit sub-units were calculated, corresponding to the metapopulation model structure presented earlier. It is important to note that Vortex requires carrying capacity values to be expressed in terms of the total population size immediately before breeding takes place, i.e., all those individuals age one year and older. Therefore, these estimates of K based on adults were converted to a total carrying capacity for all individuals at least one year of age for use in the Vortex model. Analyses of the stable age distribution in baseline models (not shown here) indicated that adults typically comprise approximately 60% of a simulated jaguar population. Final K estimates were then calculated by dividing the estimates derived from the habitat model by 0.60.

Subpopulation	Initial Population Size	K_{Adults}	K_{Total}
Sinaloa	350	1410	2350
North Sinaloa	100	1198	1997
Sonora	300	1670	2783
North Sonora	12*	135	225
South of I-10	0	27	45
North of I-10	0	74	123

* Males only

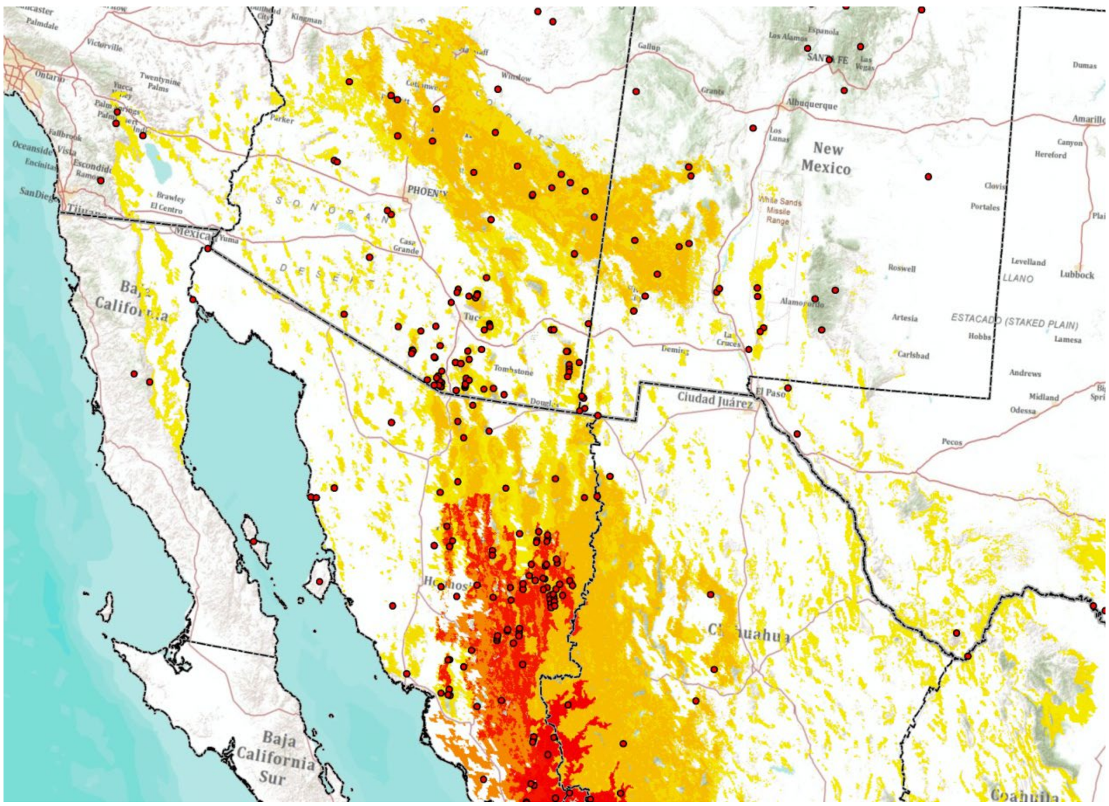


Figure 2. Graphical presentation of habitat suitability analysis for northern jaguar populations, based on the model of Hatten et al. (2005). Lighter colors represent lower habitat suitability, while darker red indicates higher suitability. See accompanying text for more information on model structure and assumptions.

Iterations and Years of Projection: All population projections (scenarios) were simulated 500 times, with each projection extending to 100 years. All simulations were conducted using *VORTEX* version 9.99b (May 2010).

Results from Simulation Models

The metapopulation scenarios presented below focus on varying two sets of input parameters:

- Rates of dispersal among subpopulations (while maintaining the relative rates across the metapopulation). Reference annual dispersal rates – those among subpopulations within Mexico – are set at 0.25%, 0.5, 0.75%, or 1.0%. Dispersal rates across the international border fence and across the I-10 corridor are then adjusted accordingly based on the information described in the previous subsection on model input parameters.
- Baseline male and female mortality rates to create anticipated stochastic growth rates for the Sonoran subpopulation (and, by extension, other subpopulations) of approximately r_s = 0.000 or 0.005. These modifications represent underlying assumptions regarding the intrinsic demographic robustness of a given subpopulation as defined by the opportunity for growth of that subpopulation over time.

A summary of selected results from these models is shown in Table 1.

Table 1. Stochastic growth rates of simulated subpopulations comprising the Northern Jaguar Population Analysis Unit. Top row of column headings gives the reference dispersal rates among jaguar subpopulations in Mexico, with dispersal rates across the international border fence and across the I-10 highway reduced according to the rules specified in the text. For each dispersal rate, results are given for alternative sets of mortality schedules that are expected to produce population growth rates of either 0.000 or 0.005 over the timeframe of the simulations. Positive growth rates indicate population growth, while negative growth rates indicate population decline. See accompanying text for additional information on model assumptions and construction.

	Annual Dispersal Rate Anticipated Subpopulation Growth Rate									
	0.00		0.25		0.50		0.75		1.00	
Subpopulation	**0.000**	**0.005**	**0.000**	**0.005**	**0.000**	**0.005**	**0.000**	**0.005**	**0.000**	**0.005**
Sinaloa	0.004	0.008	0.004	0.009	0.004	0.008	0.003	0.009	0.003	0.008
N. Sinaloa	-0.013	-0.007	0.010	0.016	0.013	0.018	0.014	0.019	0.014	0.019
Sonora	0.004	0.009	0.002	0.006	0.000	0.005	-0.001	0.005	-0.001	0.004
N. Sonora	—	—	0.009	0.012	0.010	0.015	0.011	0.017	0.013	0.018
South I-10	—	—	0.033	0.035	0.026	0.029	0.023	0.028	0.023	0.029
North I-10	—	—	0.050	0.071	0.033	0.055	0.040	0.045	0.034	0.034

Analysis of these results leads to the following observations:

- The Sinaloa population, with the largest initial size and at the southern end of the Analysis Unit, is able to sustain the levels of population growth anticipated from the mortality schedules.
- In the absence of linkage to other subpopulations, the Northern Sinaloa population displays a negative growth rate even when the anticipated long-term rate is positive. This is most likely the result of a buildup of inbreeding depression acting on this relatively small – and in this case, demographically isolated – population. This effect disappears under even the lowest level of demographic connectivity with its neighbors (Sinaloa and Sonora) as unrelated individuals move in to breed with resident animals.
- The Sonoran population, situated in the central region of the metapopulation and having one of the largest starting populations, also shows good opportunity for growth in the absence of dispersal. However when dispersal begins to occur, this subpopulation shows reduced capacity for growth under both conditions of demographic robustness (anticipated population growth rate).

Demographically, this subpopulation acts as a source of animals to neighboring subpopulations that are unable to provide an equal number of animals to replace those that have moved out of Sonora. This is a clear example of the types of complex "source-sink" dynamics that characterize the behavior of metapopulations.

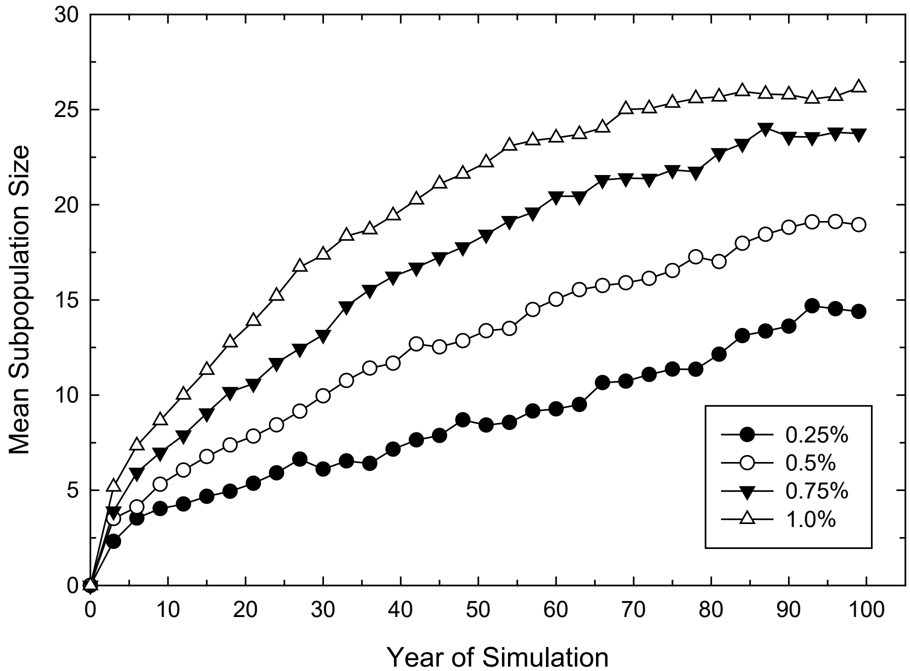
- As dispersal rates are increased across the metapopulation, those subpopulations that begin the simulation as either unoccupied (South, North I-10) or comprised only of males (North Sonora) begin to show significant levels of population growth potential. Under the lowest levels of dispersal, the United States subpopulations show higher rates of growth that reflect the fact that the initial population size is zero. As dispersal rates increase, the growth rates of these subpopulations begin to approach what is likely to be an equilibrium value.
- Under both conditions of demographic robustness (anticipated subpopulation growth rate), the overall metapopulation is expected to increase in size with a negligible risk of metapopulation extinction (specific results not shown here). However, a subpopulation south of the I-10 corridor has less than a 50% chance of persistence over the course of the simulation, and a subpopulation north of the I-10 corridor has less than a 1% probability of persistence.

The last observation above leads us to a more in-depth study of the results for the subpopulation immediately north of the international border fence, the South of I-10 subpopulation. Table 2 and Figure 3 show us that, while the probability of establishing a population of jaguars south of I-10 increases markedly as the dispersal ability increases, the resulting population remains rather small with only a very small number of adult females in the area at any point in time. There is undoubtedly some reproduction taking place in this simulated subpopulation once it is established, but the relative contribution of local reproduction to overall population stability is unclear. Additional, more detailed analysis of simulation model output is required to give us more insight into this complex dynamic.

Table 2. Results of simulations for the South of I-10 subpopulation of the Northern Jaguar Population Analysis Unit under the assumption of low demographic robustness (anticipated subpopulation growth rate = 0.000). Pr(Success) is the probability of successful subpopulation establishment after 100 years; *N* is the average total size of subpopulations that are extant at the end of the simulation; and N_f is the average number of adult females among extant subpopulations at the end of the simulation. See accompanying text for additional information on model assumptions and construction.

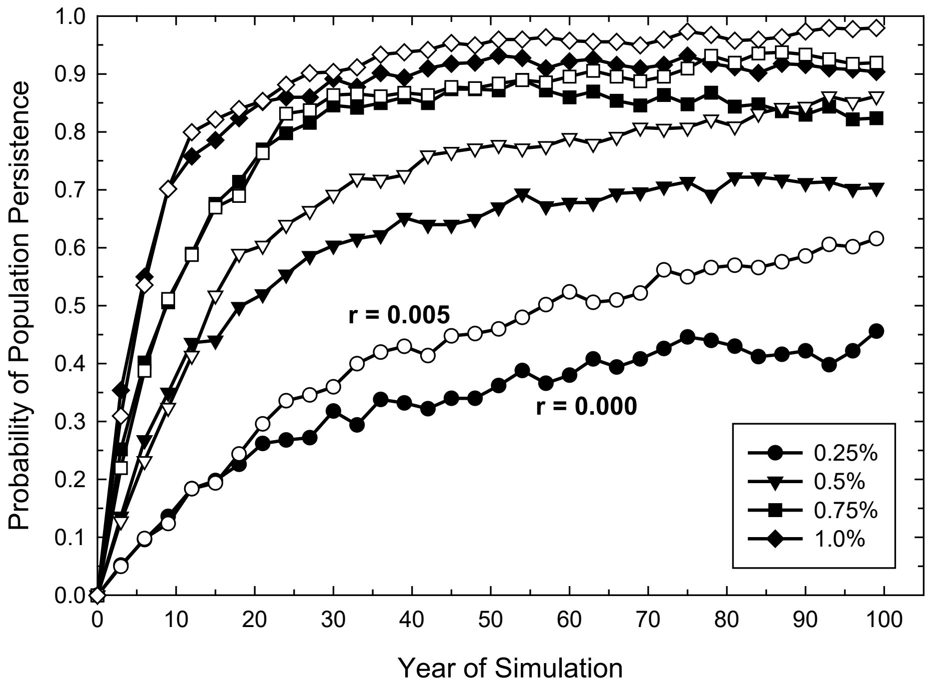
	Annual Dispersal Rate			
	0.25	**0.50**	**0.75**	**1.0**
Pr(Success)	0.464	0.694	0.810	0.910
N	14.07	19.42	23.92	26.29
N_f	4.69	6.25	7.42	8.13

Figure 3. 100-year mean abundance projections for the South of I-10 subpopulation as part of the Northern Jaguar Population Analysis Unit, under alternative levels of reference dispersal rates among subpopulation units. Underlying anticipated subpopulation growth rate (demographic robustness) is r_s = 0.000. See text for accompanying information on model assumptions and construction.



We may want to explore the relative contributions made by connectivity between subpopulations (dispersal) and subpopulation demographic robustness to the prospects for successful establishment of a jaguar population in the United States, south of the I-10 boundary. This is shown in Figure 4. As shown in Table 2, the probability of population establishment is quite high when the reference dispersal rate across the metapopulation exceeds 0.5%. At lower rates of dispersal, we see that an increase in the demographic robustness of the subpopulations from r_s = 0.000 to r_s = 0.005 leads to a relatively small increase in the probability of subpopulation establishment south of the I-10 boundary (compare the plot with black circles to that with white circles). In contrast, an increase in the reference dispersal rate from 0.0025 to 0.005 leads to a substantial increase in the probability of subpopulation establishment (compare the plot with black circles to that with black inverted triangles). It appears, then, that our model is considerably more sensitive to changes in dispersal dynamics than it is to underlying demographic dynamics – at least under the conditions simulated here and at relatively low levels of subpopulation connectivity. This leads to the hypothesis that facilitating northward dispersal of jaguars from northern Sonora, perhaps through methods designed to increase the permeability of the border fence to jaguar movement, may lead to a greater chance of successful subpopulation establishment in the United States than might be expected with significant attention paid to habitat characteristics north of the border. Such a hypothesis is open to discussion, however, as are the detailed assumptions built into the models from which it is derived.

Figure 4. Probability of establishment of a jaguar population north of the international border and south of the I-10 boundary, as a function of increasing dispersal capabilities across the metapopulation (black symbols) and under alternative assumptions of demographic robustness in each subpopulation (black vs. white symbols). See accompanying text for additional information on model assumptions and construction.



In conclusion, then, our models suggest that jaguar populations in the southern extent of the Northern Jaguar Population Analysis Unit – namely, those in Sinaloa and southern/central Sonora – are of sufficient size to remain demographically viable as long as some level of dispersal acts to reduce the potentially deleterious effects that inbreeding depression may bring to a small and relatively isolated population. Moreover, this viability is critically dependent on at least minimal opportunities for population growth of key subpopulations in the absence of dispersal so that these areas can act as demographic source populations of dispersing individuals. The strength with which a source population can supply individuals for neighboring regions is critically dependent on its intrinsic capability for growth, itself a function of the threats imposed on it by local human activity. Establishment of a jaguar population in the United States is critically dependent on (i) a demographically robust core source population in Sonora, facilitating the dispersal of individuals both north and south; (ii) the ability of the habitat in northern Sonora to sustain jaguars in the long-term and to provide key dispersal corridors to the international border; and (iii) a permeable border between northern Sonora and the region of Arizona and New Mexico south of the I-10 highway corridor.

Goals and Actions

Issue1. We have uncertainty about the subunit boundaries on the current map.
(Since we accepted our new boundaries yesterday for the purposes of the PVA - we reinterpreted this problem statement to be “uncertainty about northern jaguar distribution” in order to be able to develop longer term goals)

Goal 1.
Conduct surveys for jaguars in (a) the northern Sonora connector area, (b) north Sinaloa connector area, (c) southern Arizona, (d) New Mexico and (e) Sierra Madre Oriental – Texas region. Surveys should use consistent methods in each area; survey ~3 years to reflect year to year variation and to be repeated in regular intervals.

Issue 2. We have uncertainty about whether or not habitat suitability measures are as accurate as possible given available information.

Goal 1.
Continue ongoing analyses and publication of habitat use by northern jaguars and initiate more rigorous studies of habitat use throughout the northern jaguar range

Issue 3. We have insufficient data to justify habitat and subunit specific estimates of density and population demographics.

Goal 1.
Continue and expand studies to obtain more rigorous estimates of age and gender-specific and region-specific vital rates, including year to year variation

- Obtain better understanding of the extent to which poaching and depredation loss are compensatory with other types of mortality
- Obtain estimates of dispersal rates and distances

Issue 4. We have insufficient understanding of jaguar demographic and ecological parameters that would allow us to carry out the most accurate and meaningful PVA.

Goal 1.

- Obtain gender- and age-specific estimates dispersal rates and travel distances.
- Get accurate information on drought cycle.
- Obtain better understanding of the extent to which poaching and depredation loss are compensatory with other types of mortality.

Issue 5. We don't understand how climate change may affect demographic and ecological parameters of importance to our PVA.

Goal 1.
Obtain information on how climate change affects northern jaguar demography and ecology.

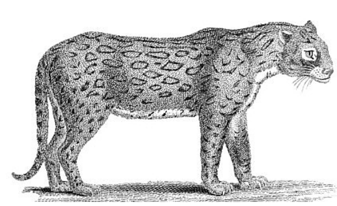
Issue 6. Border fence. (NOTE this was not part of our original problem statement list)

Goal 1.
- Seek a better understanding of the impact of border security infrastructure and operations on jaguar movement
- Seek a better understanding of the impact of highways on jaguar movement.

Northern Jaguar (*Panthera onca*)
Population and Habitat Viability Assessment

1 – 4 March, 2011
Amado, Arizona, United States

III
Working Group Report: Human – Jaguar Interaction



Working Group Report:
Human – Jaguar Interaction

Working Group Participants:
Larry Allen, Malpai Borderlands Group
David Bergman, USDA-APHIS-Wildlife Services
Gerardo Carreón, Naturalia, A.C.
Ivonne Cassaigne, UMA Sonora Assoc. para la conservación del jaguar en la Sierra Alta de Sonora
Carlos Robles Elías, El Aribabi Conservation Ranch
Rick Gerhart, Coronado National Forest
Robert Gumtow, Customs and Border Protection – U.S. Border Patrol
Karen Howe, Tohono O'odham Nation
Terry B. Johnson, Arizona Game and Fish Department
Walter Lane, Altar Valley Conservation Alliance
Rogelio Manriquez, CONANP-Priority Species
Scott Richardson, USFWS-AESO
Ma. Cristina Meléndez Torres, CEDES

Issues of Concern

The following categories of issues of importance to recovery of jaguar in the northern portion of the species' range are listed below in order of priority, defined here by the likelihood that the general issue will contribute to an increased risk of species extinction at the northern extent of its range. The number listed with each issue category is the number of votes that issue received in the group's prioritization process.

1. **Coordination/Cooperation (Stakeholders don't agree on goals or methods or prioritization of these for resource allocation) – [28]**
   - Different actions and priorities between governments. Different attitudes between researchers and government officials. Turf battles are an issue.
   - Mechanisms for conservation, voluntary vs. regulatory; voluntary vs. prescriptive. Local vs. higher levels of control.
   - Desire of a local community to shape its own future.
   - Implementing strategies more difficult than writing plans. Making it work on the ground.
   - Interdepartmental conflicts within levels of government. Tribal issues.
   - Border Issues: The border fences ~ pedestrian and vehicle barriers. Border Patrol traffic and drug smuggler traffic, illegal migrant traffic
   - Availability of Resources: We have money to spend but can't spend it in Mexico. How is money distributed? How is it made available?
   - Legal Issues: Enforcement of laws ~ no one prosecuted in Mexico for killing jaguars. Court decisions.

2. **Livestock Conflict (Livestock losses to jaguars lead to jaguar killings) – [24]**
   - Economic issues. Jaguars kill cows. Can lose everything if you are a rancher. Livestock predation leads to killing jaguars.
   - No compensation programs for ranchers who lose cattle.
   - Competition for habitat; no place else to raise cattle. No other options.
   - Lack of good management cattle practice; especially not keeping calving to a certain season
   - Over-exploitation of cattle owners on resources

3. **Conflict of Values/Cultural Differences (Conflicting values exist; jaguar conservation vs. jaguar elimination; impacted by education and cultural values) – [22]**
   - What do we prioritize? What is most important? Different values lead to different opinions about how to proceed.
   - Conflict between valuing cattle as opposed to jaguars. Mexican culture in general has no conscience about the importance of the jaguar and its conservation.
   - If teacher in school says don't kill the jaguar, child says my father at home says kill the jaguar.
   - If you go to ranchers and tell them what they "need to do"; need to tell them why it is important. And, need to take their needs and interests seriously.
   - Why are differences in values a problem? No respect from one side to the other. When highly disparate values (regardless what kind of values) you tend to discount the other's values, and you have conflict and polarization rather than working together about what to do.
   - It takes collaboration and cooperation to make conservation work, and when values are very different, there is no collaboration or cooperation. You need to bring people together; bridge the differences as a starting place.
   - Environmental Education not effective; negative attitudes about jaguar and lack of interest in wildlife conservation now exist. In Sonora, isolation of people. They live in rural areas with no chance for environmental education. Folks in the city are isolated because they don't understand what is needed in the rural areas.
   - Killing Jaguars: Kill the jaguar if it crosses land, if you just see it, for sport. Most people who kill jaguars are not hunting. All killing of jaguars is illegal. Poaching and killing due to perceived threat or a direct competitor.

4. **Competition for Prey (Humans reduce natural prey; competition causes livestock conflict & illegal killing to reduce competition) Specific to southern range – [4]**
   - Hunters want to kill same animals as jaguars prey on ~ dislike jaguars reducing available prey. Deer hunts are very expensive. Even those who use prey for food, not trophies, are affected. Also, if hunters reduce prey, then jaguars kill cattle even if they prefer to kill deer.

Information Assembly and Analysis

Issue 1. Coordination / Cooperation Among Stakeholders

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
Mitigation funds are not available in Mexico	Resources are not used in areas where the need is greatest	Ways in which mitigation funds will be used in the United States	Primarily a borderlands issue	
Higher level of activity at the border, with addition of fences, roads, and lights	Border activity will reduce movement of jaguars	There is little knowledge of routes of jaguar movement at the border		
U.S. / Mexico coordination is poor due to complexity of issues involved	If we don't change the relationships, jaguar recovery will be affected; improving coordination will improve jaguar recovery			
Court decisions are not negotiable	This is a wild card – cannot be predicted			
Seventeen different countries have started work on jaguar conservation and have made significant progress in the last 15 years, and the U.S. is not among them				
Previously mentioned jaguar conservation efforts have been severely underfunded				
For the last ten years, non-profit organizations and academic institutions have been the leaders in conservation efforts – not the governments				
There is a	This will be a slow		U.S. and Mexico	

transition underway from less government presence and leadership in becoming bigger players in jaguar conservation	process to continue			
	Government can help to unify information, efforts and programs		U.S. and Mexico	
	If the government does not choose to be a collaborative leader, this can cause harm instead of providing benefit to jaguar conservation			
Only a few UMAs consider the jaguar as an important species for conservation				

Issue 2. Conflict between livestock ranchers and jaguars leads to poaching of jaguars

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
More than 20 jaguars killed in the last five years	There are more jaguars killed that we don't know about		Sinaloa subpopulation (Sinaloa, Najarit, Jalisco JCU)	
	Jaguar poaching will continue			
More than six jaguars killed in the last five years	See above		Sonora subpopulation	
Recent survey showed 61% of people in Sonora would kill a jaguar that killed cattle	This negative attitude will not change		Sonora subpopulation	
There is a broad cattle compensation program in Mexico	It the compensation program works, it will reduce poaching or jaguar		Works differently in different areas	
Management of cattle is poor	Year-round calving practices increases risk of predation		Widespread in Mexico	
Land is overgrazed and wildlife is	Ranching reduces jaguar prey and		Widespread in Mexico	

displaced through cattle ranching	increases conflicts			
Landowners want to use their land productively	Both ranching and agriculture increases conflicts			

Issue 3a. Conflicting cultural values

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
A majority of people do not know the jaguar as a native species	If they don't know of its existence, they won't be inclined to protect it	The number of people that are aware of the jaguar in this area, and how they can be reached	U.S. and Mexico	
Some local communities receive environmental education		Need to explain education programs and make sure they are implemented	Four communities in Sonora, New Mexico and Arizona statewide education guide	Naturalia, AZGFD

Issue 3b. Different societal values of jaguars

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
NGOs and government agencies provide payment for jaguar conservation actions	If this program expands into other ranches, we could increase the value of the jaguar for the general public		Thirteen ranches in Sonora	Naturalia
Segments of society give no economical value to jaguars	No one can give specific economical value to jaguars		Mexico and U.S.	

Issue 5. Competition for prey

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
People use the same prey as jaguars	Jaguar prey are limited	We do not know prey population densities in jaguar habitat	Mexico	

Goals and Actions

Issue 1. Coordination / Cooperation Among Stakeholders

Goal 1.

Expand sources of funding that can be used on either side of the border where it will generate the greatest conservation

Action 1: Write description of the recovery planning project and take it to the trilateral meeting in May 2011
Responsible Parties: Erin Fernández (project); Rogelio Manriquez, Terry Johnson (delivery)
Cost: Low cost
Obstacles: Short time

Action 2: Create a committee focused solely on raising funds. 2011; 1st year: 5 million dollars each year for the next 5 years
Responsible Parties: Naturalia, Panthera, USFWS, CONANP, CEDES
Cost: Low cost
Obstacles: Other tasks to be accomplished first by each organization

Action 3: Institutionalize the program by agreement between USFWS and SEMARNAT (CONANP) to get certain funds and how to spend them on the jaguar conservation program.
Responsible Parties: Howard Quigley and Carlos López
Timeline: May 2011 (after the trilateral meeting)
Cost: Low cost

Action 4: Organize a meeting with PROFEPA and SEMARNAT to propose to get the money of mitigation fees into the current impacted areas. Also, identify projects to which the money can be directed.
Responsible Parties : Cristina Melendez, CEDES, with participation of: PROFEPA, SEMARNAT, SAGARPA, CONANP, Jaguar subcomitte, consejo estatal de vida Silvestre
Timeline: December 2011
Cost: Low cost
Obstacles: Collaboration of the parties

Action 5: Organize a meeting with SCT, SAGARPA to make sure that development and infrastructures or changing of land use considers wildlife conservation experts on the project
Responsible Parties: Cristina Melendez, CEDES; Rogelio Manriquez, CONANP, Rodrigo Núñez
Timeline: December 2011
Cost: Low cost
Obstacles: Collaboration of the parties

Goal 2.

Coordinate meetings between government agencies, NGOs, landowners, and academics in each region.

Action 1: Call for meeting between all of the above for the following objectives:
I) Identify kind of training or education needed at local levels

II) Work on proposals for law reinforcement
III) Identify common values between the parts (land use and conservation values should be recognized)

Responsible Parties: Rodrigo Nuñez (Jalisco and Nayarit); CEDES (Sonora); Carlos López/ government state authority (Sinaloa); AGFD, NMDGF (Arizona and New Mexico)
Timeline: April -November 2011 and once every year after
Cost: Medium cost
Obstacles: Funds and collaboration of parties

Goal 3.
Ensure that there is process for integration of PACEs and RPs so that both sides know where the priorities are and what to do. These should also include other strategies and plans with translation of all documents into Spanish and English.

Action 1: Integrate, analyze and summarize all the jaguar conservation plans and send them to Erin for her to integrate what is needed to the Jaguar Recovery Plan.
Responsible Parties: Rogelio (Conanp)
Timeline: June 2011
Cost: Low cost

Goal 4.
Mexico to develop continuing education and training for persons dealing in conservation issues at the local level.

Action 1: Identify what kind of training and where is needed. At the previous meetings identify these needs (see Goal 2, Issue 1)
Cost: Medium cost

Goal 5.
Mexico: Reinforcement and working together with other agencies (e.g., road construction)

Action 1: Trilateral meeting, at the reinforcement of law table, present proposal for training meetings.
Responsible Parties: Rogelio (CONANP)
Timeline: Initial discussion (May 2011 and 2012)
Cost: Low cost

Action 1: Training local authorities on environmental laws and ecological threats. Find environmental lawyer support.
Responsible Parties: CEDES, SEMADES and SEMANAT. AGFD, NMDGF and USFWS. Rodrigo and Cristina
Timeline: December 2012
Cost: Medium cost
Obstacles: Funds to cover lawyer agency

Goal 6.
5 year review of achievements

Issue 2: Livestock Conflict

Goal 1.
Reduce killing of jaguars in at least 50% of actual rate

Action 1: Efficiently compensate the cattle losses. Meeting with the Predator Insurance Organization (Seguro Contra Depredadores, Confederacion Nacional Ganadera) to work with the already identified problems (other types of verifications since they have not enough human resources, payment from just one animal and not necessary 10 % of their inventory, etc).
Responsible Parties: Rogelio (CONANP)
Cost: Low cost

Action 2: Create one ranch for a group of ranchers that raises cows to replace the losses on cattle depredation (self sustainable and administrated by a non-profit)
Responsible Parties: Ivonne Cassaigne
Timeline: December 2013
Cost: High cost
Obstacles: Funds

Action 3: Reinforcement of law (previous meeting with local authorities and land owners (see Goal 2, Issue 1)
Cost: Medium cost

Goal 2.
Decrease predation of cattle by jaguars in at least 50% of current rate.

Action 1: Write down a cattle management plan between researchers and the ranchers and work a pilot project.
Responsible Parties: Gerardo (Juan Carlos Bravo), Ivonne (Sonora); Rodrigo Nuñez (Jalisco)
Cost: High cost
Obsatacles: Ranchers not willing to try it, funds for covering unexpected losses.

Goal 3.
5 year review of achievements

Issue 3: Conflict with Cultural Values

Goal 1.
Find commonality amongst various cultural groups

Action 1: See Issue 1, Goal 2

Goal 2.
Increase environmental education at the following levels: schools, communities and cities in the jaguar range

Action 1: Train trainers, provide materials. (starting at 2012) Material like flyers and others are already produced by CONANP, just need to expand the numbers. CONANP in natural protected areas (special need at Cuenca del Yaqui, already working at Alamos and Ajos Bavispe). Involve SEP. Include TV and radio. Naturalia already working at Sahuaripa, bacanora, arivechi, bacatete). Jalisco and Nayarit already working at El tuito and Marismas Nacionales. CEDES and Naturalia will increase to the rest of the places depending on the funds

Responsible Parties: Rogelio (CONANP), Gerardo
Timeline: Beginning in 2012
Cost: Medium cost
Obstacles: Funds

Goal 3.

5 year review of achievements

Issue 4: Conflicts with Economic Value

Goal 1.

Promote economic alternatives for the presence of jaguar

Action 1: Help landowners to pull down government funds. Expand actual Naturalia's efforts to more ranchers, (increase 30% of their current help, each year, if funds available, for the next 5 years).
Responsible Parties: Gerardo
Timeline: Starting 2012
Cost: Medium cost
Obstacles: Funds

Action 2: Present proposal of continuous payments (not limited to a one time application) from CONAFOR and others, first to the Jaguar subcommittee and then to CONAFOR. CONANP with the new maps will also suggest all unit recovery to CONAFOR.
Responsible Parties: Cristina (CEDES); Rogelio (CONANP; priority species)
Timeline: December 2012
Cost: Medium cost

Action 3: Present proposal of "Payment for occupancy" (government or NGOs verification of the individuals in the area), first to the Jaguar subcommittee and then ask them to take it to different levels of government (federal and state government; SAGARPA, CONAFOR, SEMARNAT, CEDES and municipalities from states)
Responsible Parties: Rodrigo Núñez
Timeline: December 2012
Cost: Low cost

Action 4: Facilitate Ecotourism. Identify who is already doing these activities in the recovery unit and give training and technical support. Highlight and reinforce the community proud for jaguar.
Responsible Parties: Rodrigo Nuñez
Timeline: Starting 2011
Cost: Medium cost

Action 5: Increase 10% of actual ranchers in the incentive program that Naturalia has for pictures of wild felids. Naturalia is working an incentive program with 13 ranchers in which they get paid every month for any new pictures of felids in their cameras (given also by Naturalia). The action, depending on the funds, would be to increase the amount of ranchers in this program by 10% each year.
Responsible Parties: Gerardo (Juan Carlos Bravo)
Timeline: Starting 2012
Cost: Medium cost
Obstacles: Funds

Goal 2.
Change mindsets so that both land use and conservation values are recognized.

Action 1: Previous meetings (see Goal 2, issue 1)

Goal 3.
5 year review of achievements

Issue 5: Overpressure for Prey

Goal 1.
Increase or maintain prey base at sustainable levels

Action 1: Environmental education on subsistence hunting (reduce hunting on females). Promote and train people on getting funds (Procodes and Progan, PET, SEDESOL)
Responsible Parties: Rodrigo Nuñez
Timeline: Beginning in 2012
Cost: Medium cost

Action 2: Identify the impact of subsistence hunting in the jaguar prey species. (Research to be done in super goal 4)
Cost: High cost

Goal 2.
5 year review of achievements

Issue 6: Human Activities

Goal 1.
Decrease or regulate human activity in jaguar habitat

Action 1: Spread the word, disseminate information about roads and mines. Search advisory of groups on environmental laws for local government authorities and NGO's
Timeline: Starting April 2011.
Cost: High cost

Super Goals

Goal 1.
Identify Issues impeding conservation

Action 1: Increase participation of stakeholders (see Issue 1, Goal 2)

Action 2: Incorporate more areas for conservation of jaguar (ANP, local and federal levels, UMAs with jaguar), certificate the areas, land trust, private areas for conservation (areas de conservacion estatales).
Cost: High cost

Goal 2.
Continue and expand studies (dispersal rates, habitat use)

Action 1: Support research projects on jaguar conservation from local authorities (ej. CEDES), associations, academics and NGO's .

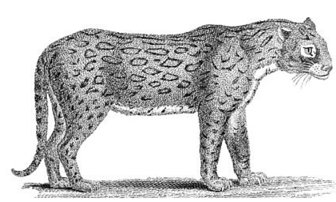
Action 2: Enforce operation, administration and infrastructure of the protected areas in the states.
Responsible Parties: Carlos, Octavio, Rodrigo, Rogelio, Cristina (CEDES), Erin, David
Cost: High cost

General Obstacles to completion of Super Goals:
Funds
Cooperation expected from each of the parts (disagreements among parts)
Unsecure places to work

Northern Jaguar (*Panthera onca*)
Population and Habitat Viability Assessment

1 – 4 March, 2011
Amado, Arizona, United States

IV
Working Group Report: Jaguar Habitat Management



Working Group Report:
Jaguar Habitat Management

Working Group Participants:
Valer Austin, Cuenca Los Ojos, A.C.
Eberardo Sanchez, Camero, CEDES
Lizardo Cruz, CONANP-Priority Species
Keith Hughes, BLM-Tucson Field Office
Eduardo Lopez, BIDA
Rodrogo Nuñez, UNAM/Chamela Cuixmala Biosphere Reserve
Octavio Rosas, COLPOS, SLP Mexico
Jim Stuart, New Mexico Department of Game and Fish
Bill Van Pelt, Arizona Game and Fish Department
Recorder: Juliette Gutierrez, USFWS-Buenos Aires National Wildlife Refuge

Issues of Concern

The following issues are presented in order of priority as determined by the working group.

1. Habitat Management Understanding

- There is a lack of habitat management on the large scale.
- We don't have adequate information on jaguar habitat needs.
  - There is a lack of information to know if habitat/corridor use needs the same for male and female
  - There needs to be a better understanding of the relationship of prey to jaguar populations and movement.
  - More information is needed to determine if competition with puma, for prey, is a hindrance to jaguar movement and success.
  - More information is needed to determine what vegetation needs are necessary for jaguar use and movement.

2. Corridor and Movement understanding

- Information is lacking as to knowing if jaguars use habitat/corridors differently in the north vs. the south. Would water be more important in the north vs. the south and has it changed historically? What is the prey base?
- We are lacking knowledge as to what barriers to movement are.
  - Changes to land use may impact movement. I.e., putting in a 4-lane road that runs along a known corridor

3. Developing Prescriptions for Optimal Habitat

- Habitat prescriptions are needed in order to provide land use ideas and standards for optimal habitat conditions for both private and agency land management. There needs to be an understanding of what the needs are before we can advise on them. Parameters/features that define species specific habitat and corridors need to be determined. I.e. % of vegetation cover recommended.

4. Human Impacts on Habitat Use by Jaguar

- There is a lack of information about impacts of border issues involving security and immigration/smuggling on jaguar populations and travel. Influence of human activity on jaguar habitat (May be part of human - jaguar interaction working group)

5. Policy and Planning Challenges

- Public land management policies and planning, i.e. grazing, deforestation, production don't tend to have a conservation focus.
    - Policy difference between countries but for same corridors
- Illegal take is an issue. There is a lack of oversight/follow up/legal ramifications and in relation to predator control, poaching, trapping, poisoning etc. despite placed regulation. (May be part of human - jaguar interaction working group)

6. Cooperation and Coordination

- There is a need for cooperation, coordination, information sharing and habitat consistency among agencies, conservation groups, researchers, ranchers, landowners of different land tenure and across international boundaries to provide for broad scale management

7. Funding

- Wildlife funding hasn't become a high enough priority to share across international boundaries.

8. Landowner Participation and Education

- There is a need to create an interest in landowner participation. Determine what incentives can be provided to entice that action.
- Landowners don't tend to take an active role in jaguar conservation.
    - There is a lack of education of landowners as to the importance of jaguars and their role in the environment. (May be part of human - jaguar interaction working group)

9. Climate Change

- More information is needed as to what impacts climate change will have on jaguar populations.

Information Assembly and Analysis

1. Habitat Management Understanding

Issue	Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
There is a lack of information to know if habitat/corridor use needs the same for male and female	There have only been 3 documented female Jaguar in the US in history	Males and female habitat use and dispersal differ. Resource availability along with kitten needs is an issue.	Small sample size with limiting factor determination	Campeche and Jalisco have shown to have a 2:1 female to male ratio. The US has very limited female use.	"Sex Matters" publication in Mexico.Boydston and Lopez.Conde et al.
There needs to be a better	There have been 86 prey	They are opportunistic	Seasonal prey and diet	NE Sonora they opt for	Nunez t al. 2000, Rosas Rosas et

understanding of the relationship of prey to jaguar populations and movement.	species identified within jaguar range	but prefer medium to large mammals	preferences	medium sized mammals. Jalisco has bigger prey diversity.	al. 2008, Lopez Gonzales et al. 2002, Seymour 1989
More information is needed to determine if competition with puma, for prey, is a hindrance to jaguar movement and success.	Jaguar and Puma overlap in diet such as ungulates	There is some competition for prey which could limit food opportunities for jaguar	To what extend do they compete for prey	Based on available data, this occurs in NE Sonora and Jalisco	Nunez et al. 2000, Rosas Rosas et al. 2008
More information is needed to determine what water/vegetation needs are necessary for jaguar use and movement.	There is localized regional habitat information available for AZ, Sonora, and Sinaloa	Water determines prey distribution. Jaguar go where prey can be found	We need more information about movement patterns of prey that draws jaguars to a place. What are the features and vegetation characteristics in habitats and corridors. Seasonally	Throughout its range. Based on available data, this is in AZ, NE Sonora	Rosas Rosas et al. 2010, Hatten et al. 2005

2. Corridor and Movement understanding

Issue	Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
Information is lacking as to knowing if jaguars use habitat/corridors differently in the north vs. the south.	In NE Sonora jaguar use riparian corridors	In the south Jaguar use riparian corridors but move to more rugged terrain further north in its range	Dispersal movement patterns. Habitat and corridor use in the rest of range.	Throughout northern jaguar recovery planning area	Rosas Rosas et al. 2006
We are lacking knowledge what is creating habitat fragmentation	There is constant increase in development of roads,	It impacts jaguar habitat and movements	Where and to what extent are jaguars being impacted. Movement data	Throughout range. Most specifically central to south Sonora	Maffei et al. 2004, Estalisticas del medio almiente in Mexico 2010

i.e. roads	urbanization, mines, fencing, lighting and other infrastructure		would help.		

4. Human Impacts on Habitat Use by Jaguar

Issue	Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
There is a lack of information about impacts of border issues involving security and immigration/smuggling on jaguar populations and travel.	In the last 10 years traffic has increased but has also moved to more rugged terrain that can also be a jaguar corridor	It impacts jaguar habitat and movements	We need statistics on the extent of activity and the impacts it has on the habitat. Do permeable fence areas stand within habitat?	Southern AZ, southern New Mexico, Northern MX	INEGI 2010

5. Policy and Planning Challenges

Issue	Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
Public land management policies and planning i.e. grazing, deforestation, production don't tend to have a conservation focus.	Species conservation is only one component of multiple use of public lands. Multiple use mandates may be in conflict with jaguar habitat conservation	Public lands may not be currently managed to promote the conservation of jaguars	Knowing how current public land management can effect jaguar and its habitat	US and Mexico	
Illegal take is an issue. There is a lack of oversight/follow up/legal ramifications and in relation	From 2000 to the present there have been ~ 20 jaguar killed despite regulations	Small populations (i.e. about 100 individuals) can not sustain this level of take. This is an	What is the killing rate throughout the northern range. What is the effect of that rate on the	Throughout the range in Mexico	

to predator control, poaching, trapping, poisoning etc. despite placed regulation.		underestimate of actual take.	jaguar population.		

6. Cooperation and Coordination

Issue	Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
There is a need for cooperation, coordination, information sharing and habitat consistency among agencies, conservation groups, researchers, ranchers, landowners of different land tenure and across international boundaries to provide for broad scale management	There is a lack of communication or coordination on jaguar habitat due to divergent goals and objectives determined by agency mandates.	Lack of coordination impedes accomplishing jaguar habitat management on the broad scale necessary for its recovery	There is no jaguar conservation plan for the state of Sonora. The national plan is general for range placement but not for management. A conservation assessment of AZ, NM and Mexico is still in draft.	Throughout the recovery area	Johnson et al. 2011

7. Funding

Issue	Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
Wildlife funding hasn't become a high enough priority to share across international boundaries	Sufficient funds are lacking for larger broad scale studies on habitat and movement such as telemetry,	It isn't a priority because there isn't a financial incentive to protecting them like there is for game animals. There isn't an incentive. Also	Where is the $???	US and Mexico	Valdez et al. 2006, CONABIO 2008

	satellite collars etc.	there is competition for funds among conservationists			

8. Landowner Participation and Education

Issue	Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
There is a need to create an interest in landowner participation. Determine what incentives can be provided to entice that action.	There is a compensation fund in the United States by the Malpai group but it has only been used once in the US. The span of where that compensation will cover was very small. In Mexico a new compensation program was started in 2010. People have been dissatisfied that they have not received the full compensation (only 40%-60%) of the animals' worth. There is an incentive program in Sonora MX UMA Jaguar Wildlife Management Area since 2003 that has been successful.	Current programs do not offer sufficient incentives to fit the needs of the jaguar or the landowners so providing habitat is not a priority	How could the program be improved to attract greater participation? We need to determine value/loss.	Primarily Mexico but across the whole range	Rosas Rosas et al. 2010 & 2010, Brown and Lopez Gonzales 2003, Johnson et al 2011

Landowners don't tend to take an active role in jaguar conservation.	There are cultural and financial reasons for not making the jaguar and its habitat a priority.	The culture and conservation need to be combined. Showing that habitat improvement for one species can benefit another. Simplification of the incentive process with entice landowners to take part.	We lack an approach to convincingly work with landowners to work on a broader management scale. We need to determine what the landowner would be comfortable with.	U.S. and Mexico	

9. Clinate Change

Issue	Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
More information is needed as to what impacts climate change will have on jaguar populations.	Jaguar has great habitat variability tolerance	Climate change will change jaguar habitat	What will the impacts be on the jaguar. Will water movement play a part.	U.S. and Mexico	

Goals and Actions

Issue 1. There is a lack of jaguar habitat conservation on the ground

Sub-Issue 1. There is a need to create an interest in landowner participation. Determine what incentives can be provided to entice that action.

Goal 1.
To have more habitat conservation implemented on the landscape

Sub-Goal 1.
To improve incentive programs for landowners

Action 1: Identify key players in CONAFOR, SEMARNAT, CONANP, SAGARPA, and local participants in workshop areas to help provide conservation incentive ideas.

Action 2: Compile a list of possible incentives and programs that can be provided to ranchers interested in taking part in environmental services..

Action 3: Conduct an association workshop, working with NGOs, for landowners, cattle associations, municipality authorities, agriculture associations, private and ejido associations, conservation districts to discuss wildlife conservation issues and stakeholder needs. A component of the workshop will involve education and explanations of ecology, the basic biology of the ecosystem, corridor values, and broad scale management using the jaguar as the key focal species. The workshop will provide a forum to interview landowners and to formulate options for both proactive and reactive incentives through mitigation, financial compensation etc. that will make jaguar conservation more palatable to landowners.

Responsible Parties: Octavio Rosas – Rosas.

Timeline: Pilot workshops will be held in Sahuaripa and Nacori Chico by 31 December 2011. Additional workshops will be held in Ciudad Obregon, Alamos and two towns in Sinaloa and Nayarit

Obstacles: Funding constraints, security for human safety, timeliness in providing incentives, and availability of workshop participants.

Issue 2. There is a lack of information on optimal jaguar habitat needs.

Sub-Issue 1. More information is needed to determine if there is prey competition between jaguar and puma.

Goal 1.

<u>To understand jaguar habitat needs for implementation</u>

Sub-Goal 1.

<u>To understand the competition for prey between jaguar and puma</u>

<u>Action 1</u>: To conduct a jaguar / puma food habit study. Study sites would be in areas where known breeding populations of jaguar occur, and studies would have to be done along the gradient of the northern range, i.e., two per state. Develop a standardized methodology for seasonally survey studies that include camera traps, track surveys, scat collection and analysis. These studies will inform us about the distribution of the two predators as well as identifying prey preference overlap.

Responsible Parties: Octavio Rosas – Rosas.

Timeline: The studies will begin by 1 October 2011 and conclude by 30 September 2016.

Obstacles: Funding availability, human safety, logistic issues such as remoteness and travel, and change in political priorities.

Sub-Issue 2. More information is needed to determine if there is prey competition between jaguar and puma.

Sub-Goal 2.

<u>To understand the relationship of prey populations trends to jaguar populations and habitats</u>

<u>Action 1</u>: In conjunction with food habit study, an additional study of ungulate abundance and trends will be implemented with the same study areas Develop a standardized survey methodology such as aerial surveys, pellet counts, track surveys or camera traps. The purpose is to quantify prey availability for jaguar to determine what prey dynamics are needed to sustain stable jaguar populations. This will serve as baseline data for implementation of future habitat management in other areas.

- Frequency of surveys at each site will be determined in methodology
- Methodology will also include precipitation and temperature data collection
- Supplemental information from ungulate population surveys will be provided by NM and AZ Departments of Game and Fish.

Responsible Parties: Eberardo Sanchez Camero in Sonora and Lizardo Cruz in Sinaloa and Nayarit.

Timeline: The studies will begin by 1 October 2011 and conclude by 30 September 2016.
Obstacles: Funding availability, human safety, logistic issues such as remoteness and travel, and change in political priorities.

Sub-Issue 3. More information is needed to determine what water / vegetation needs are required for jaguar use and movement.

Sub-Goal 3.
To understand water and vegetation structure necessary for successful jaguar habitat and movement

Action 1: To characterize vegetation where jaguar and its prey occur within the study sites discussed above. Compile existing baseline information about vegetation structure, identification of perennial or annual vegetation types, proximity to water source availability, effects of grazing, number of cattle per region, monthly weather and precipitation. Vegetation maps will be provided by Buenos Aires NWR in Arizona.
Responsible Parties: CEDES and Eberardo Sanchez Camero will do an analysis comparing data between the above vegetation and water information to jaguar records.
Timeline: The studies will begin by 1 October 2011.
Obstacles: Time constraints, funding.

Sub-Issue 4. There is a lack of information to know if habitat / corridor use needs are the same for males and females. There is also a lack of information on latitudinal differences in habitat use among jaguars.

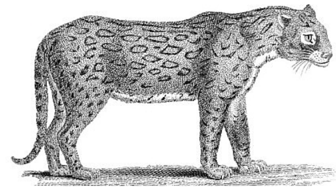
Sub-Goal 3.
To understand habitat/corridor needs of male and female jaguars, and to determine latitudinal trends in habitat use across the northern portion of the species' range

Action 1: Develop a standardized methodology for survey studies that include radio collars and radio telemetry to track movement of jaguar across the northern portion of the species' range. Northern and southern sites will be sampled. This study will inform us of habitat use by males and females across different regions of the Recovery Unit.
Responsible Parties:
Timeline: The studies will begin by 2 October 2012 and will be completed by 30 September 2017.
Obstacles: Funding. Cost of radio collars may impede timing and extent of the survey. Additional obstacles may be human safety and logistics.

Northern Jaguar (*Panthera onca*)
Population and Habitat Viability Assessment

1 – 4 March, 2011
Amado, Arizona, United States

V
Appendices



Appendix A:
Digital Mapping in Support of Recovery Planning for the Northern Jaguar[1]

Eric W. Sanderson* and Kim Fisher
Global Conservation Programs
Wildlife Conservation Society
2300 Southern Blvd
Bronx NY 10460 USA

Contact info for Eric Sanderson*
Phone: 718-220-6825
Email: esanderson@wcs.org

Summary

All project objectives and outcomes, as outlined below, were accomplished on schedule, including development of a database of relevant jaguar observations from historic times forward to the present, a geographic information system (GIS) database of spatial data appropriate for mapping the jaguar's range and considering questions of its conservation and recovery, and a simple habitat model based on a modification of the Hatten et al. 2005 model for Arizona. We also worked with the team to develop a spatially explicit system of subunits within the team's definition of an analysis unit that cross the US / Mexico border; these subunits correspond to units described in a jaguar meta-population model also developed by the recovery team. Accompanying this report, please find a data package consisting of a DVD containing GIS files and a Microsoft Access database described as below.

Project Objectives and Outcomes

The overall objective of this project is to assist the U.S. Fish and Wildlife Service (USFWS) in digital mapping aspects of recovery planning for the northern jaguar. Through the modified cooperative agreement, the Wildlife Conservation Society (WCS) agreed to:

1. Circulate a questionnaire in advance of the January 2011 Northern Jaguar Population Viability Analysis (PVA) Workshop to elicit needed feedback from Team members and collect information from the existing scientific literature or use data available from the Delphi survey conducted by USFWS.

2. Work with the Team to develop the following georeferenced spatial data layers (hereafter GIS layers) in a customized geographic information system (GIS) database with appropriate FGDC metadata documentation. Additional information will be drawn from literature sources referenced in the recent summaries of jaguar sightings relevant to the northern jaguar population and contained in a cross-referenced relational database format (e.g. Microsoft Access):

    a) Recent attributed jaguar sightings, developed from existing sources and recovery team members

[1] Final report under agreement F11AC00036 (and modification #0001) between the U.S. Fish and Wildlife Service and the Wildlife Conservation Society

b) Historical attributed jaguar sightings, developed from existing sources and recovery team members

c) The spatial extent of jaguar range recently occupied as synthesized by recovery team members

d) The spatial extent of recent self-sustaining jaguar populations as synthesized by recovery team members, including revise and incorporate additional data identified by recovery team and USFWS between the PVA and PHVA workshops such that the entire study area, as determined by Team, is covered.

e) A base map of topography, watercourses, land cover, populated places, roads, administrative units, the border pedestrian fence, border vehicle fence, and other publicly available datasets that depict variables in support of population viability and habitat analysis. It is expected there may be some variation in data quality/resolution across the international border and between states. The recovery team will determine parameters of the aforementioned variables.

f) Simple habitat models (developed at the workshops based on queries and weighted combinations of geographic layers) using information from deliverables 1-5 and the variable parameters determined by the recovery team. In addition, prepare habitat models based on cross-boundary uniform datasets using a modification of the Hatten et al. 2005 method.

2. Present draft GIS layers at the January 2011 PVA (population viability analysis) workshop for feedback from the Team.

3. Present revised GIS layers at the March 2011 Population and Habitat Viability Assessment (PHVA) workshop for feedback from the Team.

4. Submit final GIS layers to the Arizona Ecological Services Office of the U.S. Fish and Wildlife Service by April 30, 211. All GIS work will be done using ESRI's ArcGIS package. GIS layers will be presented as shapefiles and/or as a personal geodatabases.

Objective 1: Data Collection from the Recovery Team Members

WCS digitized the Delphi results from the team members and prepared maps presented at the PVA workshop showing the team the individual results and how they overlaid. The recovery team then worked through several versions of an "analysis" unit of the jaguar over the course of the two workshops and in the intervening period between workshops, which WCS digitized and revised according to instructions from the team, including a system of subunits. The final version of the analysis unit with subdivision is provided in the data package and corresponds to subunits of the meta-population model developed by the Conservation Breeding Specialist Group (CBSG) under a separate agreement and reported elsewhere. We also worked with the recovery team to develop maps for an upcoming call for proposal about jaguar monitoring along the US border.

Objective 2: Develop Digital Mapping Layers to Support Recovery Team

Objectives 2a/2b: Jaguar event database

For the United States and the northern states of Mexico, we compiled a database of jaguar observations using a record / event framework. An event refers to the experience of a person observing a jaguar. Events happen at a given place, at a given time, and vary in kind. Kinds of events include mortalities (when a person kills a jaguar), sightings (when a person observes a jaguar), observations of scat or sign attributed to a jaguar, or no observations (when a qualified person looks for a jaguar but does not see one.) Events result in a memory on behalf of the observer(s) and may also result in physical evidence (like a skull, skin or photograph.) Events are also commonly recorded, resulting in a record. A record is a written, graphical or verbal account of a jaguar event. Written records occur in newspapers, books, scientific journals, and ideally can be cited and rest in the public domain. Graphical records include photographs, paintings, or other human created representations of a jaguar (like a figurine of a jaguar). Verbal records are accounts of the event, either by someone with first hand experience, or someone who heard the story from someone else.

The presence of jaguars in the study region over time has generated a rich and interwoven literature that traces back to the first written records of Coronado in 1540. Cultural references and fossil records are also part of the history of jaguar in the region, and some of those records stretch back to the Pleistocene, more than 10,000 years before present. Each document in this literature comprises a history. A "history" is defined as a discovery, collection and analysis of information about past events. Historiography is the study of the history and methodology of the discipline of history. Although most of the writers about jaguars in the study region would not identify themselves as historians, in fact they have been practicing history – discovering, collecting and analyzing information about past events, in this case, events regarding jaguars.

Many of these histories of the jaguars have been written not only for fact-finding purposes, but also to make an argument about the presence of jaguars in this region, and in particular, within the United States. These arguments are critical to the considerations of the USFWS recovery team. Although there is considerable variation in emphasis, there seem to be two competing theories about the historical presence of the jaguar in the United States:

> "The Theory of the Wandering Jaguar" - This theory purports that jaguars have never been part of the fauna of the United States, but rather represent jaguars dispersing out of Mexico, following the chain of sky islands into Arizona and New Mexico. Writers point to the disproportionate number of males rather than females observed, inferences about the quality of habitat, and the relatively speaking small number of observations over time. Some writers also dispute some events as not representing natural jaguar populations, but are rather the result of jaguars introduced by people for purposes of hunting (Rabinowitz 1999).

> "The Theory of the Dispossessed Jaguar" – This theory suggests that jaguars were part of the fauna of the United States but were expelled through a concerted program of hunting by livestock interests and by government control, especially during the twentieth century. Ironically some of the best documented events of jaguars in the United States are mortalities caused by government hunters (Brown 1983).

Complicating interpretation of these two theories are the restrictions various writers use in documenting their histories. Some writers choose arbitrary spatial extents (e.g. the Southwest US or Arizona), others choose arbitrary temporal extents (e.g. observations only since 1900.) In part these choices are driven by practical considerations about how much material to include and what can be legibly be summarized on a written page, however in making these summaries of events, writers intentionally or unintentionally may shade the records to support their particular theory. This observation is not meant to impugn the writers, but of course one of the roles of the expert is to interpret the observations and to help the amateur or the person with less time come to some conclusions, however for the purposes of the jaguar recovery team, it seemed important to open up this historical treasure trove and to make it all available, in the words of all the writers, for the team to base its discussions on.

To this end, in support of the recovery team, the Wildlife Conservation Society created a relational database in Microsoft Access of jaguar events, summarizing as many records as we could practically handle during the grant period. This database is included in the data package. As the recovery team conversations ranged over a wide geography in Mexico and the United States, we did not bind our investigations with any a priori definitions of historical time period or geographic extent (beyond a southern limit, eventually determined by the team to include Sinaloa state in Mexico. We continued this line eastward across Mexico at approximately latitude 107 deg N). Within this database we compiled records, including the exact text of the descriptions of the jaguar event, and recording the exact text of the date and place descriptions. We also tracked citations between histories (described as “references” in the relational database structures.) If one reference cited another, we documented that citation and then followed that reference back to its source. In this way we sought to the extent possible, within the amount of effort, available to document the “original” records, as close as possible to the events, without filtering or interpretation.

As of this report , the database includes 1,045 records describing 430 distinct events compiled from 52 references (which then cite another 255 references). These 52 references are provided in Appendix 1. Note that an event is defined by the unique combination of place, time and kind of event; in some cases, multiple events may refer to the same jaguar (e.g. Macho B was observed several times over a period of several years; each observation would be cataloged as an individual event.) In general however, most events are scattered enough in time and space, it is unlikely the same jaguar is being counted twice. Note that some individuals and organizations who supplied records for the database asked that these records not be forwarded to US Fish and Wildlife Service, so these records have been deleted from the submitted database. Although the database represents an extensive investigation of these jaguar records, the database cannot be described as exhaustive. Further investigation would likely uncover additional events and certainly additional records.

The database is structured around three main tables within a Microsoft Access database: events, records, and events x records. The event table lists all the distinct events, as described above, the records table includes the data from individual records, including the full textual descriptions, and the event x records, shows which records belong to which events. Each event is given a unique numeric id (EventID), and each record also has a unique numeric id (RecordID); events are also given textual names for easy reference comprised of the observer’s name, year of the event, and place name (e.g. Harris 1939 Ramanote Canyon AZ). A form has been constructed which organizes the data by event, so that the user can read easily all the records associated with each event. ~~This~~These data was also used to generate large printouts of events and records for the PVA and PHVA workshops with the recovery team. Events are also coded by decade, event type, state, what was observed (jaguar or something else), and evidence type. Subtables provide these details within the Access database.

We also produced GIS shapefiles of the events keyed by EventID for 333 of the jaguar events. Locating points in space representing events is difficult and inexact because the great majority of events do not include exact geographic coordinates. Some events were undeemed unmappable because the locality descriptions were too coarse or inexact. Most mapped event localities are described according to place names (e.g. Chiricahua Mountains, near Kimble TX). We placed points in the centers of specific geographic features to the extent we could ascertain using the data layers described below, the ESRI Basemaps (which are available through the ArcGIS software), and Google Earth and Google Maps.

Cartographically we felt it best to show the ambiguity of location by encircling each point with a red circle based on the diameter of a male jaguar home range. We explored trying to map the polygons for mountain ranges (based on analysis of the terrain roughness data), but were not able to pursue this problem far enough to implement it across the entire dataset. The placement of points has implications for the habitat model described below.

One inescapable conclusion that emerges from the study of the jaguar events completed so far is that the jaguar's distribution the United States has changed dramatically over time. These changes have consequences in establishing a reference condition toward which to conserve and restore the jaguar under the terms of the Endangered Species Act. This conclusion was presented to the recovery team for discussion at the March 2011 PHVA meeting. In turn these decisions about what describes the "historical range of the jaguar" create the frame or context for how range-wide conservation of the jaguar is defined (for a previous treatment of this question see Sanderson et al. 2002). Understanding the ecological context of a species range – its extent and ecosystem variation – is considered essential to the conservation planning process (Redford et al. 2011; IUCN/SSC 2008).

Objective 2c. Synthesis of jaguar range

The recovery team did not complete a synthesis of the jaguar range during the term of this agreement, except in terms of the analysis unit described under Objective 1. Questions regarding what range to plan across depend on questions of what time period is an appropriate reference for USFWS planning efforts. This point was made at the March 2011 PHVA meeting. If and when the recovery team and USFWS make a decision regarding this point, the data developed through this agreement can be used to make a map indicating the recovery team's best judgment of the jaguar range.

Objective 2d. Synthesis of self-sustaining populations

As described under objective 1, we created a GIS layer describing the analysis unit and subunits, which were then subjected to population viability analysis by the CBSG team.

Objective 2e. Development of data layers for habitat mapping

We downloaded, synthesized and developed a large GIS database to support recovery team efforts. All data layers were projected to a common geographic coordinate system, documented with FGDC metadata, symbolized, and used to generate maps for the PVA and PHVA workshops. We also digitized maps provided by USFWS describing the extent of the border fence, compiling as complete as possible version of the fence as these data provided. All of these data are ~~all~~ included in the data package and are listed below.

Objective	Theme	Dataset	Source	Notes	Used in habitat analysis (2f)	Files/ directories
2e	Jaguar	BorderCats Working Group occurrence points and conservation unit polygons	Kurt Menke (kurt@birdseyeviewgis.com)	After data reconciliation efforts, decided not to use.		\bordercats
		Range-wide priority setting	Wildlife Conservation Society; Sanderson et al.	2006 data based on		\RWPS

		for jaguar	2002; Zeller et al. 2007	revision of 1999 dataset		
2e	Political	US states and counties	US Census (http://www.census.gov/geo/www/cob/st2000.html and http://www.census.gov/geo/www/cob/co2000.html)	Borders edited to match those of Mexican muncipios/states (from ESRI data). I elected to edit the US borders rather than Mexican because the US borders are generalized (http://www.census.gov/geo/www/cob/scale.html) and the Mexican borders most closely match the Rio Grande.		\uscensus
		Mexican states and muncipios	ESRI data disc packaged with ArcGIS. 2006.			\esri
		US-Mexico border (line)	Derived from US Census and ESRI data	All other border-related data (including fence segments) based on this line.		\uscensus
2e	Protected areas	CBI Protected Areas 1.1 - AZ, CA, NM, TX	http://app.databasin.org/app/pages/galleryPage.jsp?id=4b2e6723283241bd84c42a649d2ec073#tabId=datasetsTab&sortField=createDate&ascending=false	PADUS 1.1 (CBI edition). US only.		\PAs\CBI
		CEC terrestrial protected areas 2008	http://www.cec.org/Page.asp?PageID=122&ContentID=1327&SiteNodeID=499&BL_ExpandID=			\PAs\CEC_NA_PA_GEO_07_08

		WDPA Protected Areas 2010 - MX	http://www.wdpa.org/AnnualRelease.aspx	Mexico only.		\WDPA2010
		GAP stewardship	http://fws-nmcfwru.nmsu.edu/swregap/Stewardship/Default.htm	No data for CA, TX, or Mexican states.		\GAP\stewardship
2e	Elev-ation	ASTER DEM (30m)	https://wist.echo.nasa.gov/wist-bin/api/ims.cgi?mode=MAINSRCH&JS=1 "ASTER GDEM is a product of METI and NASA."	ASTERcat2 raster catalog reflects raw downloaded tiles extents. dem_aea1k is tiles mosaicked, then resampled to 1k cellsize. V2 reflects addition of southern tiles to cover expanded AOI.	X	\DEM\v2
2e	Hydro-graphy	NHD (USGS) hydrography - AZ, CA, NM, TX	ftp://nhdftp.usgs.gov/DataSets/Staged/States/FileGDB/HighResolution	US side only.		\usgs\NHD
		HydroSHEDS	http://gisdata.usgs.gov/website/HydroSHEDS/viewer.php	Cross-border.	X	\usgs\hydroSHEDS
		INEGI rivers and lakes	http://www.inegi.org.mx/geo/contenidos/recnat/hidrologia/InfoEscala.aspx	Mexico only.		\INEGI
2e	Eco-regions	WWF ecoregions	http://www.worldwildlife.org/science/data/item6373.html		X	\ecoregions\wwf
		TNC ecoregions	http://conserveonline.org/workspaces/ecoregional.shapefile/			\ecoregions\tnc
		Brown and Lowe 1980 Biotic Communities of the Southwest	US Forest Service General Technical Report RM-78	Doesn't cover entire area of interest.		\landcover\Brown_and_Lowe_TNC
2e	Land-cover	GAP land cover	http://earth.gis.usu.edu/swgap/landcover.html	No data for CA, TX, or Mexican		\GAP\landcover

				states.		
		VCF tree cover (MODIS)	https://lpdaac.usgs.gov/lpdaac/products/modis_products_table/vegetation_conversion_continuous_fields/yearly_l3_global_500m/mod44b	Cross-border; best observed landcover correlation with observations.	X	\VCF\treecover
		GLC2000 (EC Joint Commission GEM) land cover	http://bioval.jrc.ec.europa.eu/products/glc2000/products.php			\landcover\GEM
		INEGI land cover and vegetation density	http://www.inegi.org.mx/geo/contenidos/recnat/usosuelo/inf_e1m.aspx			\INEGI
2e	Habitat	USFWS Critical Habitat designations	http://criticalhabitat.fws.gov/			\fws
		Multi-species wildland block linkage corridors	http://corridordesign.org/linkages/arizona	Specific AZ corridors only.		\corridordesign.org
2e	Prey	SWReGAP species distributions: white-tailed deer, peccary, wapiti, white-nosed coati	http://fws-nmcfwru.nmsu.edu/swregap/	Workshop participants: not useful.		\GAP
2e	Human	WCS Human Influence Index	http://sedac.ciesin.columbia.edu/wildareas/	Human influence index (HII) -- non-normalized scores	X	\WCS
		Population density	CIESIN Gridded Population of the World http://sedac.ciesin.columbia.edu/gpw			\population_density

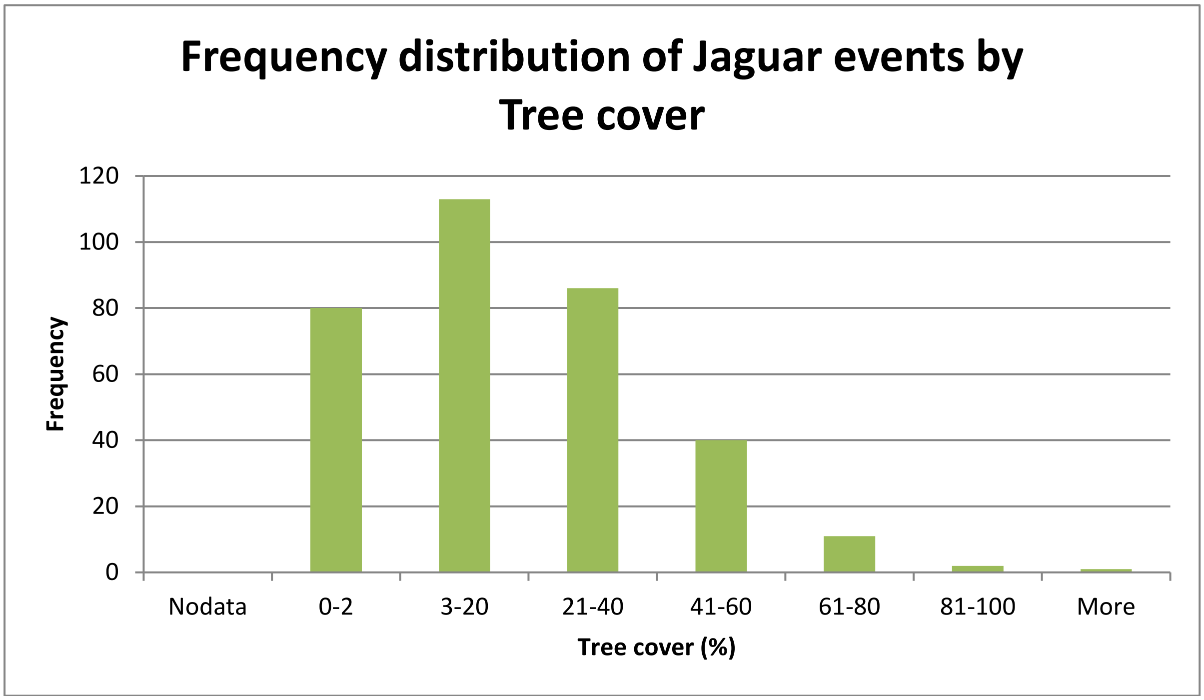
Objective 2f. Development of simple habitat maps for the northern jaguar

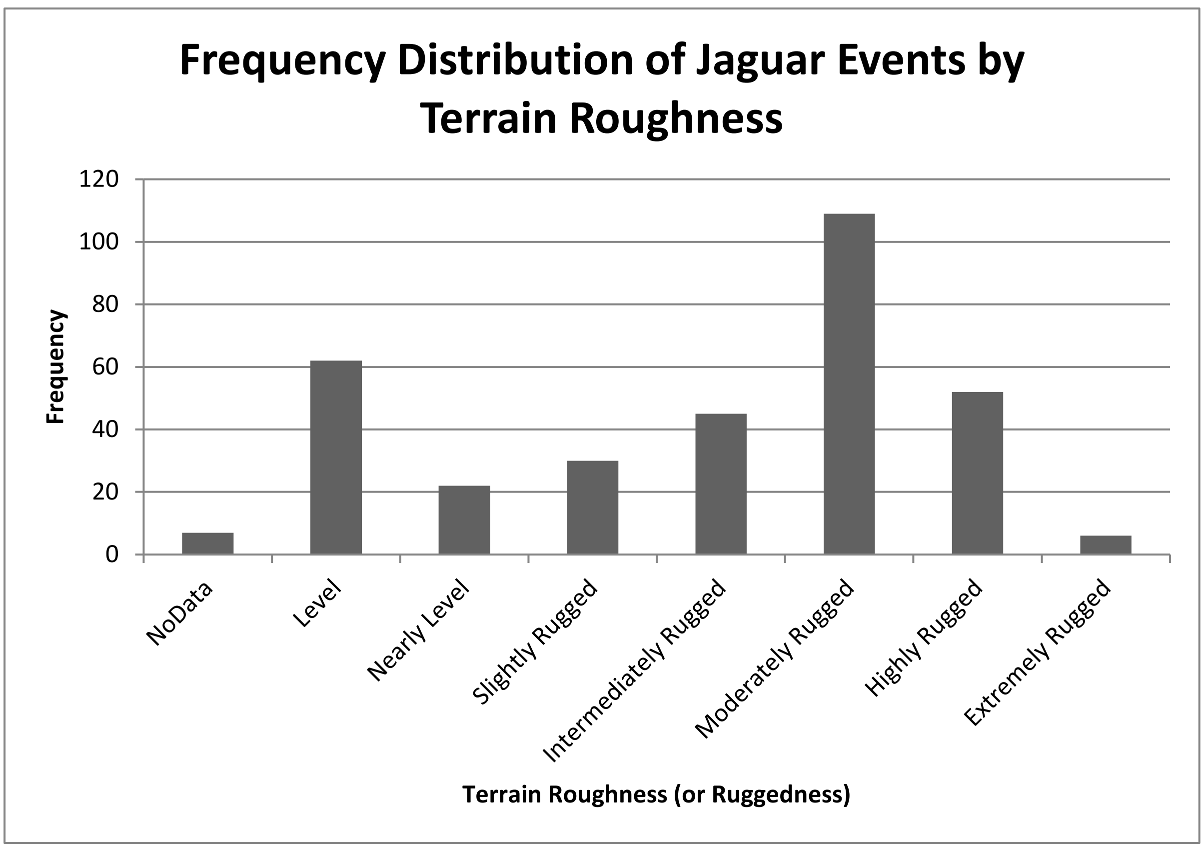
We used a subset of the data layers described under objective 2e. to produce several iterations of a simple habitat map following a modification of the Hatten et al. 2005 method. Iteration of the model were developed in concert with the recovery team. This model is only advisory; US Fish and Wildlife Service stated that they will produce the final habitat model for use by the recovery team. (E. Fernandez, pers. comm.) We replaced the Hatten et al. 2005 layers for Arizona with data layers that consistently mapped areas on across the study area, as described below. We also modified the model somewhat from Hatten et al.'s original formulation, as described below.

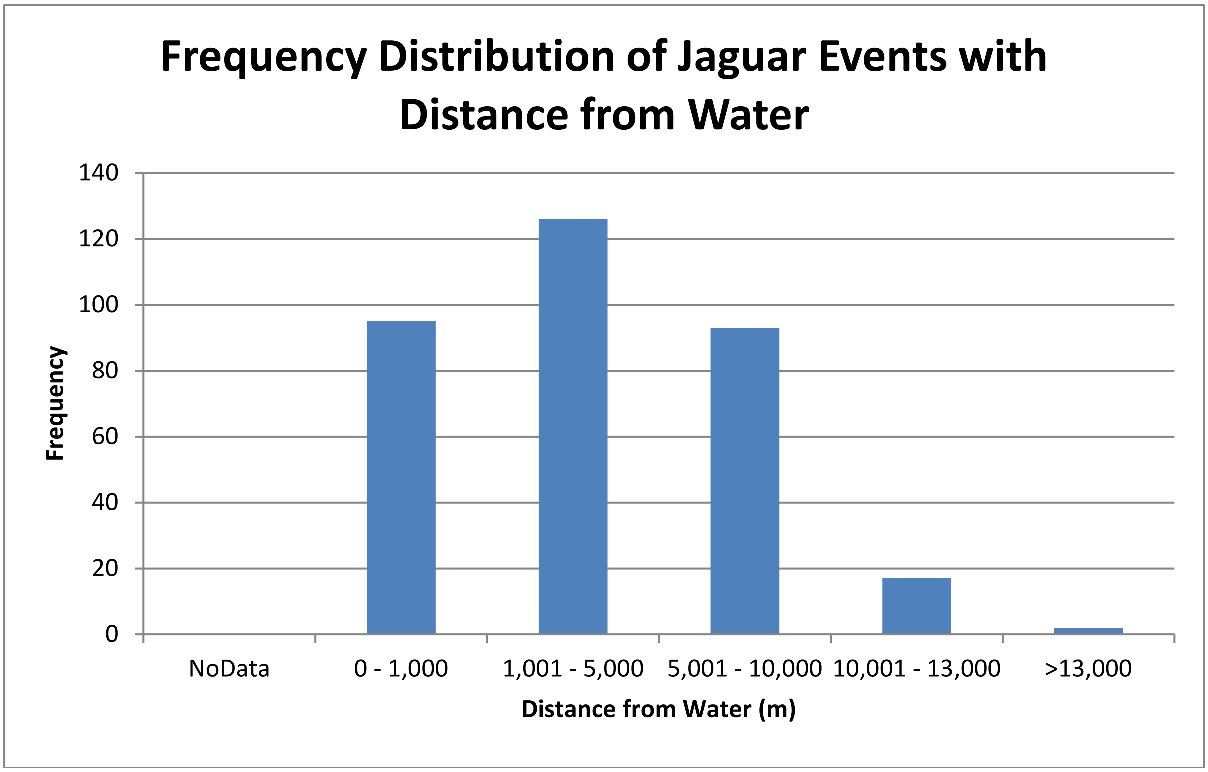
Habitat Variables	**Hatten et al. 2005**	**WCS Habitat Model**
Vegetation	Arizona GAP (Halvorson and Kunzmann 2000)	MODIS Tree cover (continuous field data) – see above under land cover
Terrain Roughness	USGS DEM	ASTER DEM – see above under elevation
Distance to Water	Arizona perennial and intermittent water and springs	Derived from HydroSHEDS – see above under hydrography
Human Influence (to exclude Cities, Ag and Rural Development Areas)	AZ State Planning Data	Human Footprint – see above under human

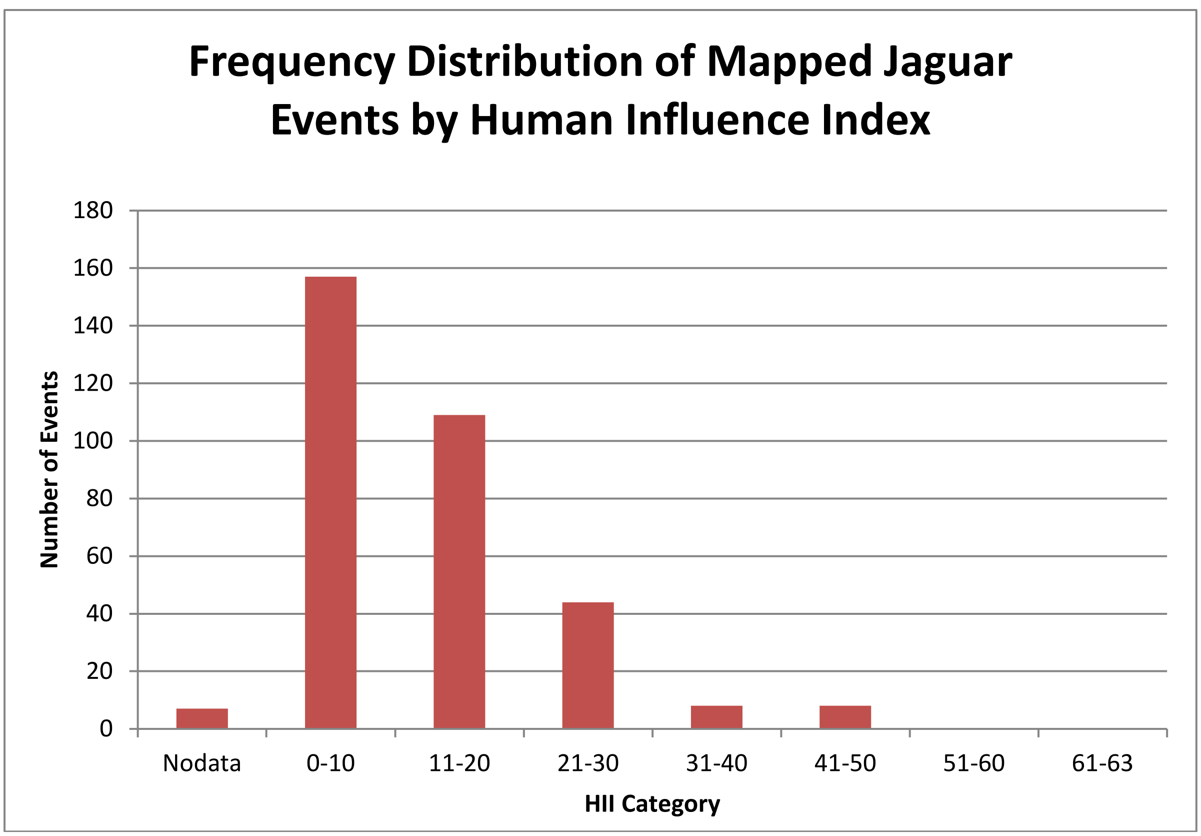
Each habitat variable is a continuous variable. Following Hatten et al. 2005 we binned these continuous variables into discrete categories and then examined the distribution of mapped jaguar events (n=333) across habitat variables to determine a categorization of the variables and selection of categories to include in the model. The analysis included areas outside the analysis unit. Because the extent of each habitat variable data layer did not encompass all of the mapped events, the total number of events for each frequency distribution analysis is slightly different. As the excluded events are in all cases marginal given the geographic definition of the analysis unit, these small differences should not affect the overall results.

The frequency distributions of jaguar events across these variables are shown below. The categories included in the model are indicated with a band of block dots on each histogram.


Frequency distribution of Jaguar events by Tree cover
120
100
80
60
40
20
0
Frequency
Nodata
0-2
3-20
21-40
41-60
61-80
81-100
More
Tree cover (%)


Frequency Distribution of Jaguar Events by Terrain Roughness
120
100
80
60
40
20
0
Frequency
NoData
Level
Nearly Level
Slightly Rugged
Intermediately Rugged
Moderately Rugged
Highly Rugged
Extremely Rugged
Terrain Roughness (or Ruggedness)


Frequency Distribution of Jaguar Events with Distance from Water
Frequency
140
120
100
80
60
40
20
0
NoData
0 - 1,000
1,001 - 5,000
5,001 - 10,000
10,001 - 13,000
>13,000
Distance from Water (m)


Frequency Distribution of Mapped Jaguar Events by Human Influence Index
Number of Events
180
160
140
120
100
80
60
40
20
0
Nodata
0-10
11-20
21-30
31-40
41-50
51-60
61-63
HII Category

We presented and discussed these frequency distributions with the recovery team. Using the GIS, we then reclassified each layer into a binary map, as follows:

Variable	1	0
Tree cover	3-60% tree cover	< 3% or > 60% tree cover
Ruggedness	intermediate, moderate, and high ruggedness	Level, nearly level, and extreme ruggedness
Distance from Water	<10 km of water	> 10 km from water
Human influence	HII < 30	HII >= 30

From these discussions we developed the following potential habitat model:

Jaguar Potential Habitat Model (values range from 0 – 5.0) =

([3-60% tree cover] + [intermediate, moderate, and high ruggedness]) (0-2)
*
[Within 10km of water] (0-1)
*
[HII < 30] (0-1)
*
[Potential habitat type weight] (0.1-2.5)

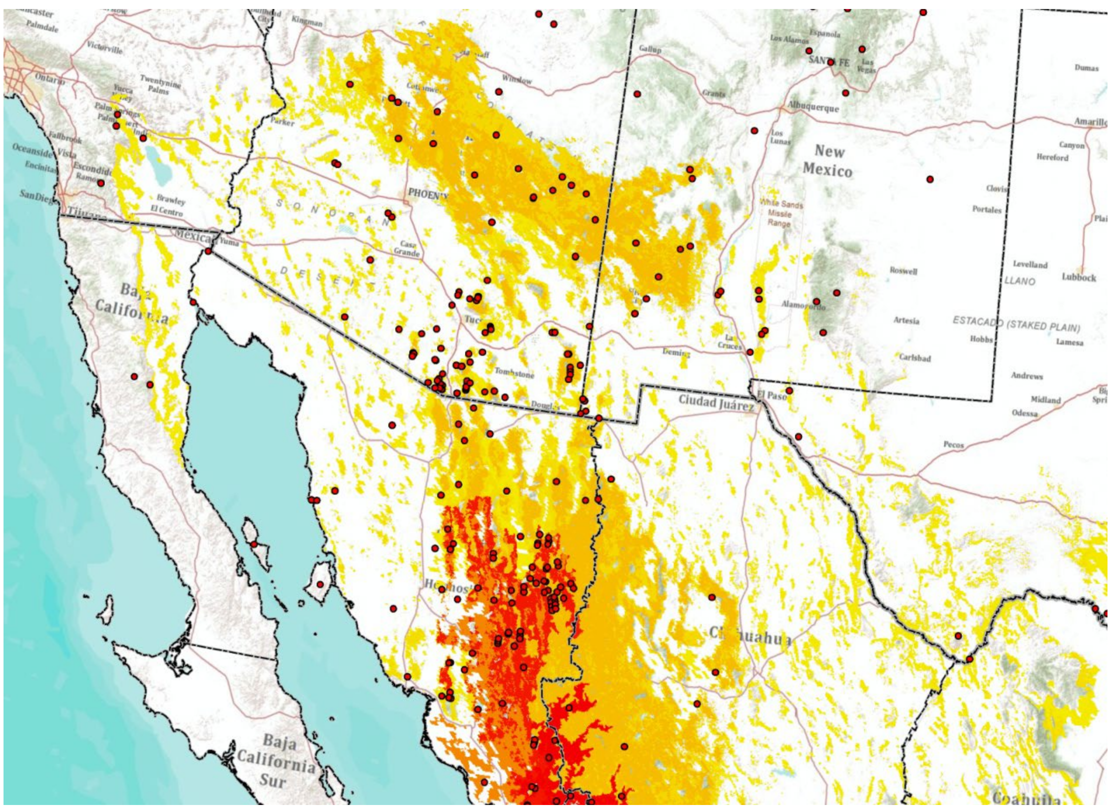
Note that the tree cover and ruggedness variable are included additively reflecting the recovery team's uncertainty about the appropriate categorization for these variables. Although jaguars are generally thought to use primarily areas with moderate tree cover within the study region, they could potentially use lower or higher cover areas, as indicated by the analysis; tree cover is not biologically required per se. Similarly jaguar are generally found within areas of intermediate to moderate ruggedness, but could be found in less rugged or more rugged areas. It is not clear whether the preference for topographic ruggedness is a response to human pressure, prey distributions or some other aspect of jaguar ecology. Including the variables like these with uncertain relationships to species biology means that areas classed as 0 for these variables may still be included in the model.

In contrast, other variables, like distance to water and human influence, were considered essential to jaguars and therefore to the model; therefore they are included multiplicatively. Areas more than 10 km from water and with a human influence score of 30 or more were excluded from the model by assigning those areas a zero. Jaguars are thought to need freshwater sources for drinking and to avoid areas with too much human pressure (though exceptions to both these overall patterns are noted.)

We also weighted the model according to potential habitat type, to represent the recovery team's sense of the suitability of different habitat types in terms of prey and cover. The potential habitat types were defined by the ecoregions that overlap the analysis unit. The recovery team examined the density of jaguars observed in some of these ecoregions and relative abundance based on their experience in others to advise on the generation of these weights. In general these weights reflect increasing habitat value in southern parts of the analysis unit relative to ecoregions in the northern part of the unit and abundance related to tropical forest types, shrubland and grassland habitats.

Potential habitat type	Relative weight
Jalisco dry forest	2.5
Sinaloan dry forest	2
Northern Mesoamerican Pacific mangroves	1.5
Sonoran-Sinaloan transition subtropical dry forest ("thornscrub")	1
Trans-Mexican Volcanic Belt pine-oak forests	0.25
Sierra Madre Occidental pine-oak forests	0.25
Arizona Mountains forests	0.25
Chihuahuan desert	0.1
Sonoran desert	0.1

The resulting map shows darker red colors indicating higher suitability values, and lighter colors indicating lower suitability.



Finally we rescaled the jaguar suitability map to represent carrying capacity for jaguar by placing seven known density estimates for jaguars in their study areas, calculating the average suitability in those study areas, and then creating a regression between the habitat suitability scores and the density estimates.

We summarized densities from seven studies and compared them to corresponding average habitat suitability within the study areas as follows:

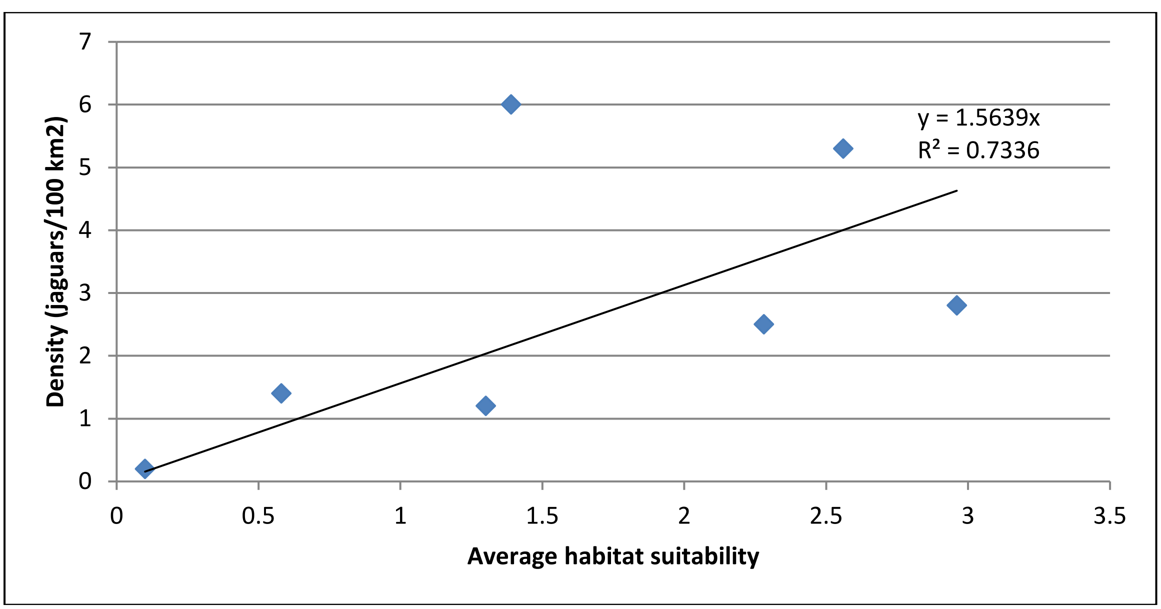
Study	Average habitat suitability	Density (jaguars/100 km^2)	Source
Jalisco-Sinaloa I	3.0	2.8	Núñez-Pérez 2011
Jalisco-Sinaloa II	1.4	6.0	R. Núñez (pers. comm.)
Jalisco-Sinaloa III	2.6	5.3	R. Núñez (pers. comm.)
Jalisco-Sinaloa IV	2.3	2.5	Coronel-Arellano et al. In press
Sonora I	0.6	1.4	Gutierrez-Gonzalez et al. In press
Sonora II	1.3	1.2	Lopez-Gonzalez and Moreno Arzate 2011; Lopez Gonzalez et al. In press
Arizona I	0.1	0.2	McCain and Childs 2008

Recovery team members provided density estimates for the first six studies in Mexico; the McCain and Childs estimate is based on their reported study area size and the number of individual jaguars seen during that study.

The regression equation indicates that for any habitat cell, the relationship of potential density to habitat suitability is

Potential density = 1.56 * Habitat Suitability Score

Note that the model is calculated to force the y-intercept of the regression through zero, since zero habitat suitability should be associated with potentially no jaguars. The regression equation was not analyzed for significance or linearity, but in general higher densities are associated with higher suitability values, though there is considerable variability. Clearly it would be desirable to have more density measurements to establish this relationship with more certainty.



From this regression equation we estimated potential jaguar carrying capacities for each of the analysis unit sub-units, corresponding to the metapopulation model developed by Dr. Phil Miller of CBSG. Since densities were based on number of adult animals, the potential carrying capacity should also be considered for adult animals (of both sexes.) However the predicted carrying capacities might be higher if the areas where the density studies were conducted were not at carrying capacity themselves. In any case these estimates should be used cautiously as they include uncertainties associated with the habitat suitability model and variation in density with respect to the habitat model. Further details may be available in the CBSG report on the population viability model.

Population subunit	**Estimated number of potential adult jaguars (i.e. carrying capacity)**
MX Sinaloa Sub-Population	1410
MX North Sinaloa Connector Area	1198
MX Sonora Sub-Population	1670
MX Northern Sonora Connector Area	135
US South of I-10 Highway	27
US North of I-10 Highway*	74
Total	**4513**

*Note: This subunit has been removed from the current definition of the Northern Jaguar Recovery Unit, but remains an entity in the population viability analysis presented elsewhere.

In summary, the following data layers/datasets were generated during the course of this project.

Objective	**Dataset**	**Source**	**Notes**	**Used in habitat analysis (2f)**	**Files/directories**
1	Jaguar monitoring RFP areas and lines	Recovery team discussions	Amended to ensure non-overlap with Tohono O'odham nation	X	\RecoveryTeam\monitoring.mdb
1	Expert-opinion range polygons for pre-1973, 1973-1997, post-1997, and recovery	Digitized and organized from Delphi questionnaire respondents			\delphi\jaguars_delphi.mdb
1/2c/2d	Population subunits for analysis	Recovery team discussions		X	\RecoveryTeam\popn_subunits\pop_subunits8.shp

2a/2b	Jaguar events database	See text. See Appendix 1 for sources.	Localities plotted against ESRI BaseMap and Google Earth data, with as much precision as locality description enables. Only points related to distinct place name locality were mapped	X	Attributes: \jaguar-records\jaguar.observations.latest.mdb Locations: \jaguar-records\events_25feb2011.shp
2a/2b	Jaguar home ranges	Derived from jaguar events	Buffered from jaguar event points for ~120 km2 areas, then clipped to land. Not used in analysis; meant to cartographically compensate for ambiguity of point locations.		\jaguar-records\events_25feb2011_buffer_clip.shp
2c	Revised Jaguar Conservation Units (JCUs)	Recovery team discussions; based on population subunits		X	\RecoveryTeam\rJCU_3.shp
2e	US-MX border fence segments	Scanned Border Patrol maps from different sources, via Erin Fernandez , USFWS	Revisions by Department of Homeland Security (DHS) ongoing		\borderpatrol\US_MX_borderfence.mdb Preliminary DHS revisions: \borderpatrol\FWS_BorderFence.mdb
2e	Terrain Ruggedness Index (TRI)	http://www.blm.gov/nstc/ecosysmod/surfland.html	Used AML written by Jacek Blaszczynski 06/1999 on 1k ASTER DEM to match method of Hatten et al. (2005) described in Riley et al. (1999) Other ruggedness candidates: SARI, Terrain Ruggedness Position (maximum), Roughness	X	\DEM\ruggedness
2f	Jaguar northern range habitat suitability	see text		X	\PHVA\habitat_latest\habitat8

2f	Predicted potential Jaguar density	see text	Suitability to density relationship derived from slope of regression of habitat suitability values on seven density estimates within analysis unit	X	\density_studies\latest_density\denshab8aea

Objective 3. Presentation at the PVA workshop

Dr. Eric Sanderson and Kim Fisher from WCS attended and presented at the PVA workshop in January 2011.

Objective 4: Presentation at the PHVA workshop

Dr. Eric Sanderson and Kim Fisher from WCS attended and presented at the PHVA workshop in March 2011.

Objective 5: Final Report and Data Package

This report and the attached data package conclude this activity. Any questions can be directed to Dr. Eric Sanderson using the contact information at the top of this report.

References

Brown, D. E. 1983. On the status of the jaguar in the Southwest. The Southwestern Naturalist 28:459–460.

Coronel-Arellano, H. Nalleli E. Lara-Díaz, Claudia N. Moreno-Arzate y Carlos A. López-González. *In press*. Density of jaguar (*Panthera onca*) in the Meseta de Cacaxtla, Sinaloa, México. Western North American Naturalist.

Gutiérrez-González, Carmina E., Gómez-Ramírez, Miguel Á. y López-González, Carlos A. *In press*. Jaguar (*Panthera onca*) density in arid lands of North America using an open population model. Oryx.

Hatten, J.R., Averill-Murray, A., and van Pelt, W.E. 2005. A spatial model of potential jaguar habitat in Arizona. Journal of Wildlife Management 69(3): 1024-1033.

IUCN/SSC. 2008. Strategic Planning for Species Conservation: A Handbook. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission. 104pp.

López González, C. A. y E. Moreno Arzate. 2011. Densidad de jaguar y abundancia de sus presas en Rosario de Tesopaco, Sonora. Reporte preparado para la CONANP-UNAM. 8 pp.

López González, C. A., E. Moreno Arzate, y G. Carreón Arroyo. In press. Densidad de jaguar y abundancia de sus presas en Rosario de Tesopaco, Sonora. In: Censo Nacional del Jaguar y sus presas: Sitios y perspectivas de conservación a diversas escalas. Cuauhtémoc Chávez, Heliot Zarza, y Gerardo Ceballos (Eds). Universidad Nacional Autonoma de Mexico-TELCEL.

McCain, E.B. and J.L. Childs. 2008. Evidence of resident jaguars (Panthera onca) in the southwestern United States and the implications for conservation. Journal of Mammalogy, 89(1):1-10.

Núñez-Pérez, R. 2011. Estimating jaguar population density using camera-traps: a comparison with radio-telemetry estimates. Journal of Zoology TBD: 1-7 (published on-line May 13, 2011). DOI: 10.1111/j.1469-7998.2011.00812.x

Rabinowitz, A. R. 1999. The present status of jaguars (*Panthera onca*) in the southwestern United States. The Southwestern Naturalist 44:96–100.

Redford, K., G. Amato, J. Baille, P. Beldomenico, E.L. Bennett, N. Clum, R. Cook, G. Fonseca, S. Hedges, S. Launay, S. Lieberman, G. M. Mace, A. Murayama, A. Putnam, J.G. Robinson, H. Rosenbaum, E.W. Sanderson, S.N. Stuart, P. Thomas, and J. Thorbjarnarson. 2011. What does it mean to successfully conserve a (vertebrate) species? Bioscience 61(6): 39-48.

Riley, S. J., S. D. DeGloria, and R. Elliot. 1999. A Terrain Ruggedness Index That Quantifies Topographic Heterogeneity. Intermountain Journal of Sciences 5:23-27.

Sanderson, E.W., Redford, K.H., Chetkiewicz, C-L.B., Medellin, R.A., Rabinowitz, A.R., Robinson, J.G., and Taber, A.B. 2002. Planning to save a species: the jaguar as model. Conservation Biology 16(1): 58-72.

Zeller, K. 2007. Updated jaguars in the new millennium dataset. Wildlife Conservation Society, Bronx, NY / Panthera Foundation, New York.

Appendix 1
Northern jaguar event record references reviewed, with number of records

Anon 1911. A Jaguar in Texas. Field and Stream (January 7, 1911) [1 record]

Arizona Game and Fish Department. 2009. Arizona Game and Fish collars first wild jaguar in United States | Arizona Wildlife News. Retrieved February 26, 2011, from http://www.azgfd.net/wildlife/conservation-news/arizona-game-and-fish-collars-first-wild-jaguar [1 record]

Arizona Game and Fish Department. 2010. Timeline of Macho B events. Retrieved February 21, 2011, from http://www.azgfd.gov/w_c/jaguar/TimeLine.shtml. [1 record]

Armstrong, D. M., J. K. Jones Jr, and E. C. Birney. 1972. Mammals from the Mexican state of Sinaloa. III. Carnivora and Artiodactyla. Journal of Mammalogy 53:48–61. [4 records]

Audubon, J. J., and J. Bachman. 1854. The viviparous quadrupeds of North America. V.G. Audubon, New York. [10 records]

Bailey, V. 1905. Biological survey of Texas: Life zones, with characteristic species of mammals, birds, reptiles and plants. North American Fauna 25:1-222. [11 records]

Bailey, V. 1931. Mammals of New Mexico. United States Department of Agriculture, Bureau of Biological Survey, Washington D.C. [15 records]

Baird, S. 1857. Part I. General report upon the zoology of the several Pacific Railroad Routes. A.O.P. Nicholson, Printer, Washington D.C. [2 records]

Baird, S. 1859. Mammals of the boundary. Page 62. Report on the U.S. Mexican Boundary Survey, under order of Lieut. Col. W.H. Emory, Washington, D.C. [9 records]

Bangs, S. F. 1899. The land mammals of peninsular Florida and the coast region of Georgia. Pages 157-235 in Proceedings of the Boston Society of Natural History. Boston Society of Natural History, Boston, MA. [1 record]

Barber, C. 1902. Notes on little-known New Mexican mammals and species apparently not recorded from the territory. Proceedings of the Biological Society of Washington 15:191-193. [2 records]

Bordercats Working Group Database. 2007. Curated by Kurt Menke, Bird's Eye GIS. [186 records]

Brickell, J., J. Lawson, J. B. Grimes. 1737. The natural history of North Carolina. Publisher, Dublin. [4 records]

Brown, D. E. 1983. On the status of the jaguar in the Southwest. The Southwestern Naturalist 28:459–460. [10 records]

Brown, D. E., and C. López-González. 2001. Borderland Jaguars: Tigres de la Frontera. Second printing. University of Utah Press. [251 records]

Burt, W. H. 1938. Faunal relationships and geographic distribution of mammals in Sonora, Mexico. Museum of Zoology, University of Michigan, Ann Arbor, MI. [13 records]

Cahalane, V. H. 1939. Mammals of the Chiricahua Mountains, Cochise County, Arizona. Journal of Mammalogy 20:418–440. [4 records]

Cory, C. B. 1896. Hunting and fishing in Florida: including a key to the water birds known to occur in the State. Estes & Lauriat. [1 record]

Daggett, P. M., and D. R. Henning. 1974. The jaguar in North America. American Antiquity 39:465–469. [28 records]

Dinets, V., and P. Polechla. 2004. Black jaguar in northern Mexico. Retrieved February 26, 2011, from http://dinets.travel.ru/blackjaguar.htm. [2 records]

Ditto, L. 1996. Letter (November 27, 1996) [7 records]

Elias, C.R. 2011. Pers. comm. [1 record]

Findley, J. S., A. Harris, D. Wilson, and C. Jones. 1975. The natural history of New Mexican mammals. University of New Mexico Press, Albuquerque, NM. [8 records]

Girmendonk, A. L. 1994. Ocelot, Jaguar and Jaguarundi sighting reports: Arizona and Sonora, Mexico. Technical Report, Arizona Game and Fish Department, Phoenix, AZ. [82 records]

Gray, J. 1857. Notice of a new species of jaguar from Mazatlan, living in the gardens of the Zoological Society. Proceedings of the Zoological Society of London:278. [1 record]

Halloran, A. 1946. The carnivores of the San Andres Mountains, New Mexico. Journal of Mammalogy 27:154-161. [3 records]

Harlan, R. 1825. Fauna americana: being a description of the mammiferous animals inhabitating North America. A. Finley, New York?. [1 record]

Hill, J. 1942. Notes on mammals of northeastern New Mexico. Journal of Mammalogy 23:75-82. [2 records]

Hock, R. 1955. Southwestern exotic felids. American Midland Naturalist 53:324-328. [30 records]

Lange, K. I. 1960. The jaguar in Arizona. Transactions of the Kansas Academy of Science (1903) 63:96–101. [57 records]

Leopold, A. 1949. A Sand County Almanac. Oxford University Press, New York. [1 record]

McCain, E. B., and J. L. Childs. 2008. Evidence of resident jaguars (*Panthera onca*) in the southwestern United States and the implications for conservation. Journal of Mammalogy 89:1–10. [10 records]

Merriam, C. 1919. Is the jaguar entitled to a place in the California fauna? Journal of Mammalogy 1:38-40. [7 records]

Moore, R. 2009. The Nature Report: jaguars in Tamaulipas. Action 4 News. July 1, 2009. Retrieved February 21, 2011, from http://www.valleycentral.com/news/news_story.aspx?id=319685. [1 record]

Navarro-Serment, C. J., C. A. López-González, and J. Gallo-Reynoso. 2005. Occurrence of Jaguar (*Panthera onca*) in Sinaloa, Mexico. The Southwestern Naturalist 50:102-106. [39 records]

New Mexico Department of Game and Fish. 2010. Reports of Jaguar (*Panthera onca*) in New Mexico, with Evaluations of their Reliability. Santa Fe, New Mexico. [29 records]

Nowak, R. M. 1975. A possible occurrence of the jaguar in Louisiana. Southwestern Naturalist 17:430-432. [7 records]

Pavlik, S. 2003. Rohonas and spotted lions: the historical and cultural occurrence of the jaguar, *Panthera onca*, among the native tribes of the American Southwest. Wicazo Sa Review 18:157-175. [51 records]

Rabinowitz, A. R. 1999. The present status of jaguars (*Panthera onca*) in the southwestern United States. The Southwestern Naturalist 44:96–100. [1 record]

Roemer, F. 1849. Texas [or Travels in Texas]. Bonn, Germany. [2 records]

Rosas-Rosas, O. C. 2006. Ecological status and conservation of jaguars (*Panthera onca*) in northeastern Sonora, Mexico. New Mexico State University, Las Cruces, NM. [5 records]

Rundel, P. W., G. M. Rizzardini, and F. M. Jaksic. 1998. Landscape disturbance and biodiversity in Mediterranean-type ecosystems. Springer, New York. [3 records]

Sage, R. B. 1846. Scenes in the Rocky Mountains: and in Oregon, California, New Mexico, Texas, and the Grand Prairies : or, Notes by the way, during an excursion of three years, with a description of the countries passed through, including their geography. Carey & Hart, Philadelphia, PA. [1 record]

Sanderson, E. W., K. H. Redford, Chetkiewicz, Cheryl-Lesley B., Medellin, Rodrigo A., Rabinowitz, Alan R., Robinson, John G., and Taber, Andrew B. 2002. Planning to save a species: the jaguar as a model. Conservation Biology 16:58-72. [9 records]

Schufeldt, R. 1929. The mountain lion, ocelots, lynxes and their kin. American Forestry 27:629-636, 659. [9 records]

Seton, E. T. 1920. The jaguar in Colorado. Journal of Mammalogy 1:241. [1 record]

Seton, E. T. 1929. Lives of game animals. Doubleday & Company, Inc., Garden City, NY. [43 records]

Strong, W. D. 1926. Indian records of California carnivores. Journal of Mammalogy 7:59-60. [3 records]

U.S. Department of Interior Office of Inspector General. 2010. Investigative report: Macho B. Page 9. Department of Interior, Washington, D.C. [1 record]

U.S. Department of the Interior Fish and Wildlife Services. 1997. Endangered and threatened wildlife and plants; final rule to extend endangered status for the jaguar in the United States. Federal Register, Washington D.C. [63 records]

Villordo-Galván, J. A., O. C. Rosas-Rosas, F. Clemente-Sánchez, J. F. Martínez-Montoya, L. A. Tarango-Arámbula, G. Mendoza-Martínez, M. D. Sánchez-Hermosillo, and L. C. Bender. 2010. The Jaguar (*Panthera onca*) in San Luis Potosí, Mexico. The Southwestern Naturalist [6 records]

Whipple, A., T. Ewand, and W. Turner. 1856. Report upon the Indian tribes. Ex. Doc 91, U.S. Congress 33, 3d session, U.S. Congress, Washington D.C. [1 record]

Young, S. 1953 (February 11, 1953) Letter [1 record]

Zeller, K. 2007. Updated jaguars in the new millennium dataset. Wildlife Conservation Society, Bronx, NY / Panthera Foundation, New York. [21 records]

Appendix B:
Workshop Participant List

Name	Affiliation	Email	Phone
Larry Allen	Malpai Borderlands Group	Larryallen350@cableone.net	505-898-3424
Valer Austin	Cuenca Los Ojos, A.C.	Cuancalosojos.org (website) vaustin@elcoronadoranch.net	
Paul Beier	Northern Arizona University	Paul.beier@nau.edu	928-523-9341
David Bergman	USDA-APHIS-Wildlife Services	David.l.bergman@aphis.usda.gov	602-870-2081
Eberardo Sánchez Camero	CEDES	ebano_02@hotmail.com	
Gerardo Carreón	Naturalia, A.C.	Conservación@naturalia.org.mx	52-662-262-1170
Luis Carrillo	IUCN/CBSG Mexico	Le.carrillo@hotmail.com	52-751-391-9001
Ivonne Cassaigne	UMA Sonora Assoc. para la conservación del jaguar en la Sierra Alta de Sonora	icassaigne@yahoo.com	52-662-215-5631
Lizardo Cruz	CONANP-Priority Species	jcruz@conanp.gob.mx	52 – 555-449-7071
Carlos Robles Elías	El Aribabi Conservation Ranch	elaribabi@telcel.blackberry.net ooshat@prodigy.net.mx	52-1-632-318-5180
Mima Falk	USFWS-Regional Office, Region 2	Mima_falk@fws.gov	520-670-6105 x225
Erin Fernandez	USFWS-AZ Ecological Services Office (AESO)	Erin_fernandez@fws.gov	520-670-6150 x238
Kim Fisher	Wildlife Conservation Society	kfisher@wcs.org	718-741-8206
Rick Gerhart	Coronado National Forest	rgerhart@fs.fed.us	520-388-8374
Robert Gumtow	Customs and Border Protection-Border Patrol	Robert.gumtow@dhs.gov	520-748-3211
Juliette Gutierrez	USFWS-Buenos Aires National Wildlife Refuge	Juliette_gutierrez@fws.gov	520-823-4251
Karen Howe	Tohono O'odham Nation	Karen.howe@tonation-nsn.gov	520-383-1513
Keith Hughes	BLM-Tucson Field Office	khughes@blm.gov	520-258-7239
Terry B. Johnson	AZ Game and Fish Department	teebeej@azgfd.gov	623-236-7707
Walter Lane	Altar Valley Conservation Alliance	wlane@headquarterswest.com	520-792-2652
Carlos López González	University of Querétaro	Cats4mex@aol.com	52-1-442-138-0437
Eduardo López	BIDA	edugomezl@gmail.com	52-662-215-5631
Rogelio Manriquez	CONANP-Priority Species	Rogelio.manriquez@conanp.gob.mx	52-555-449-7013
Phil Miller	IUCN/CBSG U.S.	pmiller@cbsg.org	952-997-9802
Rodrigo Núnez	UNAM/Chamela Cuixmala Biosphere	Proyectojaguar@gmail.com	52-443-340-6432

	Reserve		
Name	**Affiliation**	**Email**	**Phone**
Howard Quigley	Panthera	hquigley@panthera.org	406-624-6808
Becky Raboy	IUCN/CBSG U.S.	Raboyb@si.edu	
Scott Richardson	USFWS-AESO		520-670-6150 x242
Octavio Rosas	COLPOS, SLP Mexico	octaviorr@colpos.mx	52-496-963-0448
Eric Sanderson	Wildlife Conservation Society	esanderson@wcs.org	718-220-6825
Steve Spangle	USFWS-AESO	Steve_spangle@fws.gov	602-242-0210
Jim Stuart	NM Department of Game and Fish	James.stuart@state.nm.us	505-476-8107
Ma. Cristina Meléndez Torres	CEDES	mcmelendez@cedes.gob.mx mcmelendez2002@yahoo.com.mx	52-662-250-6768
Bill Van Pelt	AZ Game and Fish Department	bvanpelt@azgfd.gov	623-236-7573

Appendix C: Workshop Participant Responses to Introduction Questions

I. What is your personal goal for this workshop? What do you wish to see accomplished?

- Learn more about jaguar conservation recovery and determine how the BLM can contribute to its recovery.
- To learn as much as possible about jaguars and their habitat.
- Establish a consensus about recovery units and actions.
- Gain a better understanding of jaguar and their threats and develop reasonable goals and objectives to manage jaguars.
- Develop an approach that can be a basis for the U.S. recovery plan and assimilate information available on northern jaguars.
- Be involved in the recovery plan and be sure it does not adversely impact the borderlands region.
- Collaborate in order to develop a doable jaguar recovery plan for northern Mexico and southern U.S.
- Provide ideas for conservation of the jaguar that work in a sustainable way with cattle activities. At the same time, expose the cattle owner problems toward predation and needs from cattle ranchers. I would like to see that the implementation group considers cattle owner's needs and suggestions and help implement real actions for conservation.
- I'd like to see the jaguar alive for future generations.
- Contribute to the conservation of species at risk, particularly the jaguar. To identify the main goals and activities for the future years and the collaboration issues in general.
- Contribute to the conservation of the jaguar.
- To make collated observation and habitat data available to the team so that the best scientific decisions can be made using all available information. I'd like everyone to feel that everything necessary to proceed is available.
- I would like to see the habitat for jaguars protected and the corridors identified for landowners.
- My personal goal is to learn about the experience of the experts about conservation and give some ideas that could be useful.
- As an official representative of customs and border protection, my goal is to balance national security with recovery and conservation of all T&E species.
- To know the proposals of the US government for the conservation of the jaguar and its distribution north.
- Better understanding of jaguar life history and implications of life history for conservation planning.
- Progress toward ecologically meaningful conservation of the jaguar that fully recognizes the disparate contributions that various parts of the range can contribute.

II. What, in your view, is the primary challenge for successful recovery of the jaguar over the northern parts of its historic range over the next 25 years?

- Human population growth and border issues.
- Alternative ranching to current management and border wall removal.
- Variety of challenges from different sources and trying to address different viewpoints.
- The need to focus on Mexico with the realization that the border has essentially eliminated the US as a recovery unit.
- Human development including the border fence and border management.
- Border fences, drug and human traffic, and urban development.
- To tell stakeholders of the importance (ecologically and economically) to conserve jaguars long-term.
- Eliminate or decrease poaching or killing of jaguars and conservation of its habitat and corridors.
- Education
- Connectivity, education, and to involve landowners.
- Habitat fragmentation, international cooperation, illegal immigration, and predator control in Mexico.
- Definitions of historical range, current range, population units etc. Habitat characterization is difficult because of lack of geographic and reliability precision. The team's results will vary wildly dependent on the choices about data.
- Increase in human activities that impact the jaguar such as roads, agricultural expansion, loss of water, and vegetation cover.
- To accept that we are sharing the same issue. We are losing part of the habitat but we also need to cover other necessities.
- From the border law enforcement point of view, we must gain control of the remote areas where the jaguar would flourish. Our enforcement efforts have shifted illegal traffic into the mountains. This is the last resort of smugglers. Once that traffic is shut down, jaguar-human interaction in the mountains will be curtailed.
- There are great opportunities for success if the US and Mexico could cooperate.
- Increasing human tolerance in Mexico. Increasing landscape permeability to allow female jaguars to expand into suitable areas.
- Habitat fragmentation and loss with consequent impacts on jaguar and prey populations.

III. What do you wish to contribute to this workshop?

- Information on BLM land management, projects etc.
- Experience on the ground with the species
- Experience with the cultural relationship that jaguar has to indigenous groups throughout its range as it ties into habitat
- A down-to-earth working reality
- Information from a New Mexico perspective
- Knowledge of needs of working ranches and landscapes
- To identify effective jaguar corridors between the US and Mexico and to apply sound science to estimate jaguar presence/absence
- Suggestions and ideas from a group of ranchers interested in the conservation of jaguar parallel to cattle activities
- Education in Mexico
- Cooperative activities between the US and Mexico
- An understanding of habitat factors and rancher concerns
- Provide comprehensive data to allow the team to make these range/habitat decisions
- My knowledge of our area along the border and my knowledge of the animals using the waterways and the mountain ranges. Also, knowledge of particular threats in our area of the border such as the expansion of Route 2 from a 2-lane to 4-lane highway
- To summarize the efforts that we have been doing in our different positions. No controversial issues; but constructive ones
- Anything that is required of me. I am here to assist as much as possible
- My work experience in monitoring and conservation in Sonora
- Some thoughtful questions and focused thinking
- As much knowledge and historical perspective as possible

Appendix D:
Population Viability Analysis and Simulation Modeling

Phil Miller, Bob Lacy
Conservation Breeding Specialist Group (IUCN / SSC)

Introduction

Thousands of species and populations of animals and plants around the world are threatened with extinction within the coming decades. For the vast majority of these groups of organisms, this threat is the direct result of human activity. The particular types of activity, and the ways in which they impact wildlife populations, are often complex in both cause and consequence; as a result, the techniques we must use to analyze their effects often seem to be complex as well. But scientists in the field of conservation biology have developed extremely useful tools for this purpose that have dramatically improved our ability to conserve the planet's biodiversity.

Conservation biologists involved in recovery planning for a given threatened species usually try to develop a detailed understanding of the processes that put the species at risk, and will then identify the most effective methods to reduce that risk through active management of the species itself and/or the habitat in which it lives. In order to design such a program, we must engage in some sort of predictive process: we must gather information on the detailed characteristics of proposed alternative management strategies and somehow predict how the threatened species will respond in the future. A strategy that is predicted to reduce the risk by the greatest amount – and typically does so with the least amount of financial and/or sociological burden – is chosen as a central feature of the recovery plan.

But how does one predict the future? Is it realistically possible to perform such a feat in our fast-paced world of incredibly rapid and often unpredictable technological, cultural, and biological growth? How are such predictions best used in wildlife conservation? The answers to these questions emerge from an understanding of what has been called "the flagship industry" of conservation biology: Population Viability Analysis, or PVA. And most methods for conducting PVA are merely extensions of tools we all use in our everyday lives.

The Basics of PVA

To appreciate the science and application of PVA to wildlife conservation, we first must learn a little bit about population biology. Biologists will usually describe the performance of a population by describing its demography, or simply the numerical depiction of the rates of birth and death in a group of animals or plants from one year to the next. Simply speaking, if the birth rate exceeds the death rate, a population is expected to increase in size over time. If the reverse is true, our population will decline. The overall rate of population growth is therefore a rather good descriptor of its relative security: positive population growth suggests some level of demographic health, while negative growth indicates that some external process is interfering with the normal population function and pushing it into an unstable state.

This relatively simple picture is, however, made a lot more complicated by an inescapable fact: wildlife population demographic rates fluctuate unpredictably over time. So if we observe that 50% of our total population of adult females produces offspring in a given year, it is almost certain that more or less than 50% of our adult females will reproduce in the following year. And the same can be said for most all other demographic rates: survival of offspring and adults, the numbers of offspring born, and the offspring sex ratio will almost always change from one year to the next in a way that usually defies precise prediction. These variable rates then conspire to make a population's growth rate also change unpredictably from year to year. When wildlife populations are very large – if we consider seemingly endless herds of wildebeest on the savannahs of Africa, for example – this random annual fluctuation in population growth is of little to no consequence for the future health and stability of the population. However, theoretical and practical study of population biology has taught us that populations that are already small in size, often defined in terms of tens to a few hundred individuals, are affected by these fluctuations to a much greater extent – and the long-term impact of these fluctuations is always negative. Therefore, a wildlife population that has been reduced in numbers will become even smaller through this fundamental principle of wildlife biology. Furthermore, our understanding of this process provides an important backdrop to considerations of the impact of human activities that may, on the surface, appear relatively benign to larger and more stable wildlife populations. This self-reinforcing feedback loop, first coined the "extinction vortex" in the mid-1980's, is the cornerstone principle underlying our understanding of the dynamics of wildlife population extinction.

Once wildlife biologists have gone out into the field and collected data on a population's demography and used these data to calculate its current rate of growth (and how this rate may change over time), we now have at our disposal an extremely valuable source of information that can be used to predict the *future* rates of population growth or decline under conditions that may not be so favorable to the wildlife population of interest. For example, consider a population of primates living in a section of largely undisturbed Amazon rain forest that is now opened up to development by logging interests. If this development is to go ahead as planned, what will be the impact of this activity on the animals themselves, and the trees on which they depend for food and shelter? And what kinds of alternative development strategies might reduce the risk of primate population decline and extinction? To try to answer this question, we need two additional sets of information: 1) a comprehensive description of the proposed forest development plan (how will it occur, where will it be most intense, for what period of time, etc.) and 2) a detailed understanding of how the proposed activity will impact the primate population's demography (which animals will be most affected, how strongly will they be affected, will animals die outright more frequently or simply fail to reproduce as often, etc.). With this information in hand, we have a vital component in place to begin our PVA.

Next, we need a predictive tool – a sort of crystal ball, if you will, that helps us look into the future. After intensive study over nearly three decades, conservation biologists have settled on the use of computer simulation models as their preferred PVA tool. In general, models are simply any simplified representation of a real system. We use models in all aspects of our lives; for example, road maps are in fact relatively simple (and hopefully very accurate!) 2-dimensional representations of complex 3-dimensional landscapes we use almost every day to get us where we need to go. In addition to making predictions about the future, models are very helpful for us to: (1) extract important trends from complex processes, (2) allow comparisons among different types of systems, and (3) facilitate analysis of processes acting on a system.

Recent advances in computer technology have allowed us to create very complex models of the demographic processes that define wildlife population growth. But at their core, these models attempt to replicate simple biological functions shared by most all wildlife species: individuals are born, some grow to adulthood, most of those that survive mate with individuals of the opposite sex and then give birth to one or more offspring, and they die from any of a wide variety of causes. Each species may have its own special set of circumstances – sea turtles may live to be 150 years old and lay 600 eggs in a single event, while a chimpanzee may give birth to just a single offspring every 4-5 years until the age of 45 – but the fundamental biology is the same. These essential elements of a species' biology can be incorporated into a computer program, and when combined with the basic rules for living and the general characteristics of the population's surrounding habitat, a model is created that can project the demographic behavior of our real observed population for a specified period of time into the future. What's more, these models can explicitly incorporate random fluctuations in rates of birth and death discussed earlier. As a result, the models can be much more realistic in their treatment of the forces that influence population dynamics, and in particular how human activities can interact with these intrinsic forces to put otherwise relatively stable wildlife populations at risk.

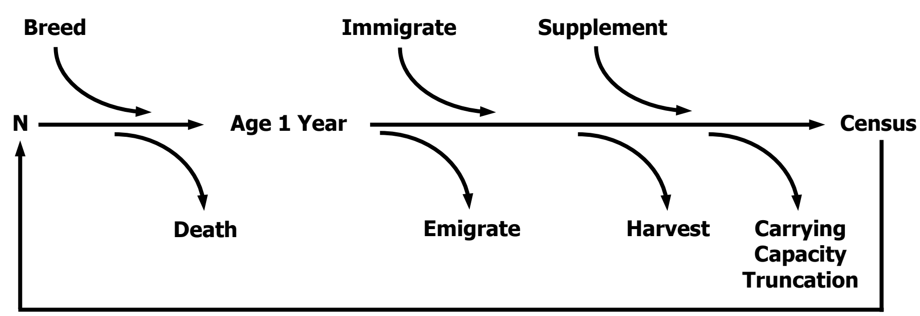
Many different software packages exist for the purposes of conducting a PVA. Perhaps the most widely-used of these packages is *VORTEX*, developed by the IUCN Conservation Breeding Specialist Group (CBSG) for use in both applied and educational environments. *VORTEX* has been used by CBSG and other conservation biologists for more than 15 years and has proved to be a very useful tool for helping make more informed decisions in the field of wildlife population management.

The *VORTEX* Population Viability Analysis Model

For the analyses presented here, the *VORTEX* computer software (Lacy 1993a) for population viability analysis was used. *VORTEX* models demographic stochasticity (the randomness of reproduction and deaths among individuals in a population), environmental variation in the annual birth and death rates, the impacts of sporadic catastrophes, and the effects of inbreeding in small populations. *VORTEX* also allows analysis of the effects of losses or gains in habitat, harvest or supplementation of populations, and movement of individuals among local populations.

Density dependence in mortality is modeled by specifying a carrying capacity of the habitat. When the population size exceeds the carrying capacity, additional morality is imposed across all age classes to bring the population back down to the carrying capacity. The carrying capacity can be specified to change linearly over time, to model losses or gains in the amount or quality of habitat. Density dependence in reproduction is modeled by specifying the proportion of adult females breeding each year as a function of the population size.

VORTEX Simulation Model Timeline



Events listed above the timeline increase N, while events listed below the timeline decrease N.

VORTEX models loss of genetic variation in populations, by simulating the transmission of alleles from parents to offspring at a hypothetical genetic locus. Each animal at the start of the simulation is assigned two unique alleles at the locus. During the simulation, *VORTEX* monitors how many of the original alleles remain within the population, and the average heterozygosity and gene diversity (or "expected heterozygosity") relative to the starting levels. *VORTEX* also monitors the inbreeding coefficients of each animal, and can reduce the juvenile survival of inbred animals to model the effects of inbreeding depression.

VORTEX is an *individual-based* model. That is, *VORTEX* creates a representation of each animal in its memory and follows the fate of the animal through each year of its lifetime. *VORTEX* keeps track of the sex, age, and parentage of each animal. Demographic events (birth, sex determination, mating, dispersal, and death) are modeled by determining for each animal in each year of the simulation whether any of the events occur. Events occur according to the specified age and sex-specific probabilities. Demographic stochasticity is therefore a consequence of the uncertainty regarding whether each demographic event occurs for any given animal.

VORTEX requires a lot of population-specific data. For example, the user must specify the amount of annual variation in each demographic rate caused by fluctuations in the environment. In addition, the frequency of each type of catastrophe (drought, flood, epidemic disease) and the effects of the catastrophes on survival and reproduction must be specified. Rates of migration (dispersal) between each pair of local populations must be specified. Because *VORTEX* requires specification of many biological parameters, it is not necessarily a good model for the examination of population dynamics that would result from some generalized life history. It is most usefully applied to the analysis of a specific population in a specific environment.

Further information on *VORTEX* is available in Lacy (2000) and Miller and Lacy (2003).

Results reported for each scenario include:

Deterministic r -- The deterministic population growth rate, a projection of the mean rate of growth of the population expected from the average birth and death rates. Impacts of harvest, inbreeding, and density dependence are not considered in the calculation. When $r = 0$, a population with no growth is expected; $r < 0$ indicates population decline; $r > 0$ indicates long-term population growth. The value of r is approximately the rate of growth or decline per year.

The deterministic growth rate is the average population growth expected if the population is so large as to be unaffected by stochastic, random processes. The deterministic growth rate will correctly predict future population growth if: the population is presently at a stable age distribution; birth and death rates remain constant over time and space (i.e., not only do the probabilities remain constant, but the actual number of births and deaths each year match the expected values); there is no inbreeding depression; there is never a limitation of mates preventing some females from breeding; and there is no density dependence in birth or death rates, such as a Allee effects or a habitat “carrying capacity” limiting population growth. Because some or all of these assumptions are usually violated, the average population growth of real populations (and stochastically simulated ones) will usually be less than the deterministic growth rate.

Stochastic r -- The mean rate of stochastic population growth or decline demonstrated by the simulated populations, averaged across years and iterations, for all those simulated populations that are not extinct. This population growth rate is calculated each year of the simulation, prior to any truncation of the population size due to the population exceeding the carrying capacity. Usually, this stochastic r will be less than the deterministic r predicted from birth and death rates. The stochastic r from the simulations will be close to the deterministic r if the population growth is steady and robust. The stochastic r will be notably less than the deterministic r if the population is subjected to large fluctuations due to environmental variation, catastrophes, or the genetic and demographic instabilities inherent in small populations.

P(E) -- the probability of population extinction, determined by the proportion of, for example, 500 iterations within that given scenario that have gone extinct in the simulations. "Extinction" is defined in the *VORTEX* model as the lack of either sex.

N -- mean population size, averaged across those simulated populations which are not extinct.

SD(N) -- variation across simulated populations (expressed as the standard deviation) in the size of the population at each time interval. SDs greater than about half the size of mean N often indicate highly unstable population sizes, with some simulated populations very near extinction. When SD(N) is large relative to N, and especially when SD(N) increases over the years of the simulation, then the population is vulnerable to large random fluctuations and may go extinct even if the mean population growth rate is positive. SD(N) will be small and often declining relative to N when the population is either growing steadily toward the carrying capacity or declining rapidly (and deterministically) toward extinction. SD(N) will also decline considerably when the population size approaches and is limited by the carrying capacity.

H -- the gene diversity or expected heterozygosity of the extant populations, expressed as a percent of the initial gene diversity of the population. Fitness of individuals usually declines proportionately with gene diversity (Lacy 1993), with a 10% decline in gene diversity typically causing about 15% decline in survival of captive mammals (Ralls et al. 1988). Impacts of inbreeding on wild populations are less well known, but may be more severe than those observed in captive populations (Jiménez et al. 1994). Adaptive response to natural selection is also expected to be proportional to gene diversity. Long-term conservation programs often set a goal of retaining 90% of initial gene diversity (Soulé et al. 1986). Reduction to 75% of gene diversity would be equivalent to one generation of full-sibling or parent-offspring inbreeding.

Strengths and Limitations of the PVA Approach

When considering the applicability of PVA to a specific issue, it is vitally important to understand those tasks to which PVA is well-suited as well as to understand what the technique is not well-designed to deliver. With this enhanced understanding will also come a more informed public that is better prepared to critically evaluate the results of a PVA and how they are applied to the practical conservation measures proposed for a given species or population.

The dynamics of population extinction are often quite complicated, with numerous processes impact the dynamics in complex and interacting ways. Moreover, we have already come to appreciate the ways in which demographic rates fluctuate unpredictably in wildlife populations, and the data needed to provide estimates of these rates and their annual variability are themselves often uncertain, i.e., subject to observational bias or simple lack of detailed study over relatively longer periods of time. As a result, the elegant mental models or the detailed mathematical equations of even the most gifted conservation biologist are inadequate for capturing the detailed nuances of interacting factors that determine the fate of a wildlife population threatened by human activity. In contrast, simulation models can include as many factors that influence population dynamics as the modeler and the end-user of the model wish to assess. Detailed interactions between processes can also be modeled, if the nature of those interactions can be specified. Probabilistic events can be easily simulated by computer programs, providing output that gives both the mean expected result and the range or distribution of possible outcomes.

PVA models have also been shown to stimulate meaningful discussion among field biologists in the subjects of species biology, methods of data collection and analysis, and the assumptions that underlie the analysis of these data in preparation for their use in model construction. By making the models and their underlying data, algorithms and assumptions explicit to all who learn from them, these discussions become a critical component in the social process of achieving a shared understanding of a threatened species' current status and the biological justification for identifying a particular management strategy as the most effective for species conservation. This additional benefit is most easily recognized when PVA is used in an interactive workshop-type setting, such as the Population and Habitat Viability Assessment (PHVA) workshop designed and implemented by CBSG.

Perhaps the greatest strength of the PVA approach to conservation decision-making is related to what many of its detractors see as its greatest weakness. Because of the inherent uncertainty now known to exist in the long-term demography of wildlife populations (particularly those that are small in size), and because of the difficulties in obtaining precise estimates of demographic rates through extended periods of time collecting data in the field, accurate predictions of the future performance of a threatened wildlife population are effectively impossible to make. Even the most respected PVA practitioner must honestly admit that an accurate prediction of the number of mountain gorillas that will roam the forests on the slopes of the eastern Africa's Virunga Volcanoes in the year 2075, or the number of polar bears that will swim the warming waters above the Arctic Circle when our great-grandchildren grow old, is beyond their reach. But this type of difficulty, recognized across diverse fields of study from climatology to gambling, is nothing new: in fact, the Nobel Prize-winning physicist Niels Bohr once said "Prediction is very difficult, especially when it's about the future." Instead of lamenting this inevitable quirk of the physical world as a fatal flaw in the practice of PVA, we must embrace it and instead use our very cloudy crystal ball for another purpose: to make **relative**, rather than **absolute**, predictions of wildlife population viability in the face of human pressure.

The process of generating relative predictions using the PVA approach is often referred to as sensitivity analysis. In this manner, we can make much more robust predictions about the relative response of a simulated wildlife population to alternate perturbations to its demography. For example, a PVA practitioner may not be able to make accurate predictions about how many individuals of a given species may persist in 50 years in the presence of intense human hunting pressure, but that practitioner can speak with considerably greater confidence about the relative merits of a male-biased hunting strategy compared to the much more severe demographic impact typically imposed by a hunting strategy that prefers females. This type of comparative approach was used very effectively in a PVA for highly threatened populations of tree kangaroos (*Dendrolagus* sp.) living in Papua New Guinea, where adult females are hunted preferentially over their male counterparts. Comparative models showing the strong impacts of such a hunting strategy were part of an important process of conservation planning that led, within a few short weeks after a participatory workshop including a number of local hunters (Bonaccorso et al., 1998), to the signing of a long-term hunting moratorium for the most critically endangered species in the country, the tenkile or Scott's tree kangaroo (*Dendrolagus scottae*).

PVA models are necessarily incomplete. We can model only those factors which we understand and for which we can specify the parameters. Therefore, it is important to realize that the models often underestimate the threats facing the population, or the total risk these threats collectively impose on the population of interest. To address this limitation, conservation biologists must try to engage a diverse body of experts with knowledge spanning many different fields in an attempt to broaden our understanding of the consequences of interaction between humans and wildlife.

Additionally, models are used to predict the long-term effects of the processes presently acting on the population. Many aspects of the situation could change radically within the time span that is modeled. Therefore, it is important to reassess the data and model results periodically, with changes made to the conservation programs as needed (see Lacy and Miller (2002), Nyhus et al. (2002) and Westley and Miller (2003) for more details).

Finally, it is also important to understand that a PVA model by itself does not define the goals of conservation planning of a given species. Goals, in terms of population growth, probability of persistence, number of extant populations, genetic diversity, or other measures of population performance must be defined by the management authorities before the results of population modeling can be used.

Further Reading

Beissinger, S. and D. McCullough (eds.). 2002. *Population Viability Analysis*. University of Chicago Press, Chicago.

Bonaccorso, F., P. Clark, P.S. Miller and O. Byers. 1999. Conservation Assessment and Management Plan for the Tree Kangaroos of Papua New Guinea and Population and Habitat Viability Assessment for Matschie's Tree Kangaroo (*Dendrolagus matschei*): Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Gilpin, M.E., and M.E. Soulé. 1986. Minimum viable populations: processes of species extinction. Pages 19 – 34 in: Soulé, M.E. (ed.). *Conservation Biology: The Science of Scarcity and Diversity*. Sinauer Associates, Sunderland, MA.

Jiménez, J.A., K.A. Hughes, G. Alaks, L. Graham, and R.C. Lacy. 1994. An experimental study of inbreeding depression in a natural habitat. *Science* 266:271-273.

Lacy, R.C. 1993. Impacts of inbreeding in natural and captive populations of vertebrates: implications for conservation. *Perspectives in Biology and Medicine* 36:480-496.

Lacy, R.C. 2000. Structure of the *VORTEX* simulation model for population viability analysis. *Ecological Bulletins* 48:191-203.

Lacy, R.C., and P.S. Miller. 2002. Incorporating human activities and economics into PVA. Pages 490 – 510 in: Beissinger, S. and D. McCullough (eds.), *Population Viability Analysis*. University of Chicago Press, Chicago.

Miller, P.S., and R.C. Lacy. 2005. *VORTEX: A Stochastic Simulation of the Extinction Process. Version 9 User's Manual*. IUCN SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Morris, W.F., and D.F. Doak. 2002. *Quantitative Conservation Biology: Theory and Practice of Population Viability Analysis*. Sinauer Associates, Sunderland, MA.

Nyhus, P.J., F.R. Westley, R.C. Lacy, and P.S. Miller. 2002. A role for natural resource social science in biodiversity risk assessment. *Society and Natural Resources* 15:923-932.

Ralls, K., J.D. Ballou, and A. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. *Conservation Biology* 2:185-193.

Reed, J.M., L.S. Mills, J.B. Dunning Jr., E.S. Menges, K.S. McKelvey, R. Frye, S.R. Beissinger, M.-C. Anstett, and P.S. Miller. 2002. Emerging issues in population viability analysis. *Conservation Biology* 16:7-19.

Soulé, M., M. Gilpin, W. Conway, and T. Foose. 1986. The millennium ark: How long a voyage, how many staterooms, how many passengers? *Zoo Biology* 5:101-113.

Westley, F.W., and P.S. Miller (eds.). 2003. *Experiments in Consilience: Integrating Social and Scientific Responses to Save Endangered Species*. Island Press, Washington, DC.

Sequence of program flow

(1) The seed for the random number generator is initialized with the number of seconds elapsed since the beginning of the 20th century.

(2) The user is prompted for an output file name, duration of the simulation, number of iterations, the size below which a population is considered extinct, and a large number of population parameters.

(3) The maximum allowable population size (necessary for preventing memory overflow) is calculated as:

$$K_{max} = (K + 3s)(1 + L)$$

in which *K* is the maximum carrying capacity (carrying capacity can be specified to change during a simulation, so the maximum carrying capacity can be greater than the initial carrying capacity), *s* is the annual environmental variation in the carrying capacity expressed as a standard deviation, and *L* is the specified maximum litter size.

(4) Memory is allocated for data arrays. If insufficient memory is available for data arrays then N_{max} is adjusted downward to the size that can be accommodated within the available memory and a warning message is given. In this case it is possible that the analysis may have to be terminated because the simulated population exceeds N_{max}. Because N_{max} is often several-fold greater than the likely maximum population size in a simulation, a warning that it has been adjusted downward because of limiting memory often will not hamper the analyses.

(5) The deterministic growth rate of the population is calculated from mean birth and death rates that have been entered. Algorithms follow cohort life-table analyses (Ricklefs 1979). Generation time and the expected stable age distribution are also calculated. Life-table calculations assume constant birth and death rates, no limitation by carrying capacity, no limitation of mates, no loss of fitness due to inbreeding depression, and that the population is at the stable age distribution. The effects of catastrophes are incorporated into the life table analysis by using birth and death rates that are weighted averages of the values in years with and without catastrophes, weighted by the probability of a catastrophe occurring or not occurring.

(6) Iterative simulation of the population proceeds via steps 7 through 26 below.

(7) The starting population is assigned an age and sex structure. The user can specify the exact age-sex structure of the starting population, or can specify an initial population size and request that the population be distributed according to the stable age distribution calculated from the life table. Individuals in the starting population are assumed to be unrelated. Thus, inbreeding can occur only in second and later generations.

(8) Two unique alleles at a hypothetical neutral genetic locus are assigned to each individual in the starting population and to each individual supplemented to the population during the simulation. *VORTEX* therefore uses an infinite alleles model of genetic variation. The subsequent fate of genetic variation is tracked by reporting the number of extant neutral alleles each year, the expected heterozygosity or gene diversity, and the observed heterozygosity. The expected heterozygosity, derived from the Hardy-Weinberg equilibrium, is given by

$$H_e = 1 - \sum \left(p_i^2\right)$$

in which p_i is the frequency of allele *i* in the population. The observed heterozygosity is simply the proportion of the individuals in the simulated population that are heterozygous. Because of the starting assumption of two unique alleles per founder, the initial population has an observed heterozygosity of 1.0 at the hypothetical locus and only inbred animals can become homozygous. Proportional loss of heterozygosity through random genetic drift is independent of the initial heterozygosity and allele frequencies of a population (Crow and Kimura 1970), so the expected heterozygosity remaining in a simulated population is a useful metric of genetic decay for comparison across scenarios and populations. The mean observed heterozygosity reported by *VORTEX* is the mean inbreeding coefficient of the population.

(9) For each of the10 alleles at five non-neutral loci that are used to model inbreeding depression, each founder is assigned a unique lethal allele with probability equal to 0.1 x the mean number of lethal alleles per individual.

(10) Years are iterated via steps 11 through 25 below.

(11) The probabilities of females producing each possible size litter are adjusted to account for density dependence of reproduction (if any).

(12) Birth rate, survival rates, and carrying capacity for the year are adjusted to model environmental variation. Environmental variation is assumed to follow binomial distributions for birth and death rates and a normal distribution for carrying capacity, with mean rates and standard deviations specified by the user. At the outset of each year a random number is drawn from the specified binomial distribution to determine the percent of females producing litters. The distribution of litter sizes among those females that do breed is maintained constant. Another random number is drawn from a specified binomial distribution to model the environmental variation in mortality rates. If environmental variations in reproduction and mortality are chosen to be correlated, the random number used to specify mortality rates for the year is chosen to be the same percentile of its binomial distribution as was the number used to specify reproductive rate. Otherwise, a new random number is drawn to specify the deviation of age- and sex-specific mortality rates from their means. Environmental variation across years in mortality rates is always forced to be correlated among age and sex classes.

The carrying capacity (*K*) for the year is determined by first increasing or decreasing the carrying capacity at year 1 by an amount specified by the user to account for changes over time. Environmental variation in *K* is then imposed by drawing a random number from a normal distribution with the specified values for mean and standard deviation.

(13) Birth rates and survival rates for the year are adjusted to model any catastrophes determined to have occurred in that year.

(14) Breeding males are selected for the year. A male of breeding age is placed into the pool of potential breeders for that year if a random number drawn for that male is less than the proportion of adult males specified to be breeding. Breeding males are selected independently each year; there is no long-term tenure of breeding males and no long-term pair bonds.

(15) For each female of breeding age, a mate is drawn at random from the pool of breeding males for that year. If the user specifies that the breeding system is monogamous, then each male can only be paired with a single female each year. Males are paired only with those females which have already been selected for breeding that year. Thus, males will not be the limiting sex unless there are insufficient males to pair with the successfully breeding females.

If the breeding system is polygynous, then a male may be selected as the mate for several females. The degree of polygyny is determined by the proportion of males in the pool of potential breeders each year.

The size of the litter produced by that pair is determined by comparing the probabilities of each potential litter size (including litter size of 0, no breeding) to a randomly drawn number. The offspring are produced and assigned a sex by comparison of a random number to the specified birth sex ratio. Offspring are assigned, at random, one allele at the hypothetical genetic locus from each parent.

(16) The genetic kinship of each new offspring to each other living animal in the population is determined. The kinship between new animal *A*, and another existing animal, *B*, is

$$f_{AB} = 0.5(f_{MB} + f_{PB})$$

in which f_{ij} is the kinship between animals *i* and *j*, *M* is the mother of *A*, and *P* is the father of *A*. The inbreeding coefficient of each animal is equal to the kinship between its parents, $F = f_{MP}$, and the kinship of an animal to itself is $f_A = 0.5(1 + F)$. (See Ballou 1983 for a detailed description of this method for calculating inbreeding coefficients.)

(17) The survival of each animal is determined by comparing a random number to the survival probability for that animal. In the absence of inbreeding depression, the survival probability is given by the age and sex-specific survival rate for that year. If a newborn individual is homozygous for a lethal allele, it is killed. Otherwise, the survival probability for individuals in their first year is

$$e^{-b(1-\Pr[Lethals])F}$$

multiplied by
in which *b* is the number of lethal equivalents per haploid genome, and Pr[*Lethals*] is the proportion of this inbreeding effect due to lethal alleles.

(18) The age of each animal is incremented by 1.

(19) If more than one population is being modeled, migration among populations occurs stochastically with specified probabilities.

(20) If population harvest is to occur that year, the number of harvested individuals of each age and sex class are chosen at random from those available and removed. If the number to be removed do not exist for an age-sex class, *VORTEX* continues but reports that harvest was incomplete.

(21) Dead animals are removed from the computer memory to make space for future generations.

(22) If population supplementation is to occur in a particular year, new individuals of the specified age class are created. Each immigrant is assumed to be genetically unrelated to all other individuals in the population, and it carries the number of lethal alleles that was specified for the starting population.

(23) The population growth rate is calculated as the ratio of the population size in the current year to the previous year.

(24) If the population size (*N*) exceeds the carrying capacity (*K*) for that year, additional mortality is imposed across all age and sex classes. The probability of each animal dying during this carrying capacity truncation is set to $(N - K)/N$, so that the expected population size after the additional mortality is *K*.

(25) Summary statistics on population size and genetic variation are tallied and reported.

(26) Final population size and genetic variation are determined for the simulation.

(27) Summary statistics on population size, genetic variation, probability of extinction, and mean population growth rate are calculated across iterations and output.