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Arizona-New Mexico Jaguar Conservation Team
Research Committee

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RESEARCH RECOMMENDATIONS FOR THE ARIZONA-NEW MEXICO JAGUAR CONSERVATION TEAM

ABSTRACT

This report summarizes the results of the first two meetings of the Arizona-New Mexico Jaguar Conservation Team (JAG Team) Research Committee and outlines future research that will guide the JAG Team in sound conservation management of jaguars in the United States. Research objectives were identified and approved by the JAG Team. These objectives are to describe and quantify (1) the current distribution and (2) habitat requirements of jaguars in southeastern Arizona and southwestern New Mexico. The second meeting focused on selecting study methods to achieve these objectives.

The Borderlands Jaguar Detection Project has been conducting noninvasive jaguar research in southeastern Arizona since 1999. There is great need to expand upon the current research by conducting similar noninvasive presence/absence surveys in adjacent mountain ranges with potential jaguar habitat in southeastern Arizona and southwestern New Mexico. It is also necessary to gather more detailed data on jaguar habitat selection in the Borderlands Region. Home range size, composition of habitat types, travel routes, movement patterns, and diet are currently unknown for jaguars in the northern extent of their range. This type of information is critical for the JAG Team to successfully manage for healthy jaguar conservation in the American Southwest.

After virtual extirpation from the Southwest during the mid-1900's, jaguars have been rediscovered in portions of their former range in the United States, changing the way we think about their current status and distribution. However, we must look ahead and take the next step towards responsible jaguar conservation and apply serious, in-depth and objective research on the jaguar in the borderlands region. We emphasize the unique situation of wild jaguars currently occupying portions of southeastern Arizona and recommend investigations to learn as much as possible on the specific habitat selection and habitat requirements of these jaguars while the opportunity exists. We propose a combination of studies. These would include noninvasive presence/absence surveys to determine the current status and distribution. Once jaguars are located, we recommend conducting detailed studies of their habitat selection and ecology using a combination of GPS telemetry and noninvasive monitoring techniques.

INTRODUCTION

The jaguar (*Panthera onca*), the largest wild felid in the western hemisphere, is at great risk throughout its range due to habitat loss and persecution by livestock owners (Swank and Teer 1989). The jaguar once ranged from the southwestern United States through Mexico and Central America south to Argentina (Seymour 1989); however, a recent and rigorous range-wide assessment determined that jaguars currently occupy only 46% of their former range (Sanderson et al. 2002). The species was virtually extirpated from the Southwest during the mid 1900's. However, jaguars have recently been photographed in remote portions of the Sky Island mountains of southeastern Arizona and southwestern New Mexico (Glenn 1996, Childs 1998, Rabinowitz 1999, Brown and Lopez Gonzalez 2001, Lopez Gonzalez and Brown 2002, Valdez et al. 2002, McCain and Childs 2006). This has sparked hope for the jaguar's return to its historic range in the southwestern United States and has reinforced the urgency for conservation work to identify and protect potential habitat and movement corridors across the border between the southwestern United States and northern Mexico.

Jaguars were common residents in the American Southwest until the beginning of the 20th century when western expansion resulted in loss of habitat, and predator control programs wiped out remaining populations (Rabinowitz 1999). Historic sightings in the Southwest indicate a scattered and declining resident jaguar population into the 1940's, after which point an occasional jaguar was documented every five to ten years until the present date. The last documented female jaguar in Arizona was killed in 1963 in the White Mountains of central Arizona (Brown and Lopez Gonzalez 2001). Thought to have long been extinct in the United States, the jaguar was not included in the U. S. Fish and Wildlife Service's 1972 list of federally endangered species. The Endangered Species Act, therefore, only addressed jaguars outside of the United States. With the assumption that jaguars were extinct in the United States, the great cat was forgotten.

On 7 March 1996, houndsman Warner Glenn was hunting mountain lions in the Peloncillo Mountains along the Arizona/New Mexico border, when his dogs bayed an adult male jaguar on a rocky cliff. Instead of reaching for his rifle, this rancher reached for his camera and took several photographs before he gathered his dogs, tipped his hat, and rode away (Glenn 1996). Six months later, on 31 August 1996 mountain lion hunter Jack Childs and his party treed, photographed, and videotaped another adult male jaguar in the Baboquivari Mountains of southern Arizona. They too gathered their dogs and gratefully walked away (Childs 1998).

Following these two sightings, the Arizona-New Mexico Jaguar Conservation Team (JAG Team) was formed to further protect and manage the jaguar in Arizona and New Mexico. This team of state and federal wildlife and land management agencies, university biologists, conservation groups, local landowners, ranchers and concerned citizens was formed in a collaborative approach to protect and manage the jaguar in Arizona and New Mexico. The U.S. Fish and Wildlife Service and the Arizona Game and Fish Department agreed that the jaguar was a resident species in Arizona and formally listed the jaguar as an endangered species in the United States on 21 August 1997. The Jaguar Conservation Team initiated a jaguar monitoring project later that year by supplying trail cameras to both Warner Glenn and Jack Childs. These cameras were set in the vicinity of the two 1996 jaguar sightings in the Peloncillo Mountains along the

Arizona/New Mexico border and in the Baboquivari Mountains southwest of Tucson, Arizona. The monitoring efforts in the Baboquivari Mountains were expanded in 2001 to become the Borderlands Jaguar Detection Project when the Wildlife Conservation Society of the Bronx Zoo and the Phoenix Zoo funded houndsman Jack Childs to conduct a more in-depth monitoring effort along the Arizona/Sonora border. This research was supported by the JAG Team when the Arizona Game and Fish Department supplied film, batteries, and developing costs.

On 9 December 2001, an adult male jaguar was photographed in Arizona with a trail camera about 6.5 km north of the Mexican border. On 7 August 2003 20 months later, the same jaguar was photographed again at another monitoring station 6 km further north in the same mountain range. It was determined that both detections were of the same individual because the distinguishing spot patterns on the animal's right side were identical in both photographs.

During the summer of 2004 the Borderlands Jaguar Detection Project expanded when the Wildlife Department at Humboldt State University joined the team, and graduate student Emil McCain began his Master's thesis research on the project. The monitoring effort increased in intensity, from 13 camera stations and track/scat transects to more than 30, and encompassed a larger area of more remote and inaccessible mountains. Since its initiation in 2001, the Borderlands Jaguar Detection Project has documented 49 jaguar data points inside the state of Arizona. This includes 30 photographs, 10 scat/fecal samples and 9 sets of tracks. These detections confirm the presence of two adult male jaguars and possibly a third unidentified individual in southeastern Arizona. Analysis of DNA extracted from scat samples is underway to determine gender, individual identity and potential relatedness to jaguars in the closest known breeding population in East-Central Sonora, Mexico.

This project has produced the only current biological information available on jaguars in the northern extent of their range over the past half century. This information will prove invaluable to the U.S. Fish and Wildlife Service, Arizona Game and Fish Department, and New Mexico Game and Fish Department in making responsible management decisions regarding jaguar conservation and habitat protection in the American Southwest. Although this project has been very successful in documenting the presence of jaguars in the United States, policy makers are still lacking enough information to know exactly what size and type of habitats jaguars need, and therefore which areas need to be protected to ensure jaguar recovery in the United States. Since we have confirmed the presence of these animals in Arizona, it is critical to expand our research efforts to more comprehensively study Arizona jaguars. At this point, the current status and distribution of the jaguar in the Borderlands Region of southeastern Arizona and southwestern New Mexico remain unknown. Even though jaguars have recently been documented in a portion of southeastern Arizona (McCain and Childs 2006) virtually nothing is known about their specific habitat utilization or habitat requirements. It is important to better understand exactly where these animals currently occur and which habitats their territories and travel routes encompass. In order for the U.S. Fish and Wildlife Service, Arizona Game and Fish Department, and New Mexico Game and Fish Department to provide the necessary protection for the jaguar, we must know which areas jaguars currently occupy and which habitats they require to recover in the Southwestern United States.

When the JAG Team was formed, a Scientific Advisory Group, consisting of renowned jaguar biologists with extensive jaguar research experiences from Central and South America, was established. Since its formation, the Scientific Advisory Group has recommended biological research to gather information on current jaguar distribution, travel routes, and habitat utilization in the Borderlands Region of southeastern Arizona and southwestern New Mexico. Multiple studies have been completed on jaguars throughout Central and South America, and in those areas their ecology, home range, habitat use, and general natural history requirements are understood (Schaller and Crawshaw 1980, Rabinowitz and Nottingham 1986, Emmons 1987, Crawshaw and Quigley 1991, Quigley and Crawshaw 1992, Scognamillo et al. 2003). However, very little is known about jaguars in the arid environment of the American Southwest and Northwest Mexico (Rabinowitz 1999, Brown and Lopez Gonzales 2001, Boydston and Lopez Gonzales 2005). The JAG Team and the wildlife management agencies of the Southwest face the challenge of managing for the conservation of a species about which little is known (Treves and Karanth 2003, Hatten et al. 2005).

Much of the existing information on Jaguars in the United States comes from historical records of jaguars killed by hunters, trappers, and predator control agents in the Southwest during the past century (Rabinowitz 1999). Brown and Lopez Gonzales (2001) followed up on these historical records of jaguars in the Borderlands Region, and several authors have used those locations to map potential jaguar habitat in Arizona (Hatten et al. 2003, Boydston and Lopez Gonzales 2005, Hatten et al. 2005) and New Mexico (Menke and Hayes 2003). However, these maps are generated from the small dataset of about 50 locations from anecdotal historic accounts that span the entire 20th century. Furthermore, these historical accounts are not standardized, and the resulting unsubstantiated data has produced theoretical maps that need to be ground tested with hard scientific studies (Morrison 2001, Hatten et al. 2005). These maps are insufficient for determining jaguar distribution and habitat requirements in the borderlands region. In July 1997, Dr. Alan Rabinowitz, Director of Science for the Wildlife Conservation Society, International Programs, and active member of the JAG Team's Scientific Advisory Group, wrote a letter to the JAG Team stating that: "There is a need to gather biological data using techniques such as camera traps, track pads, and scent stations. At some point it might become advisable to radio collar a few individuals to determine their movement patterns and behavior in the southern United States and northern Mexico".

The Scientific Advisory Group of the JAG Team has recommended that, if the opportunity presents itself, it would be advisable to place a radio collar on a jaguar to gather baseline information on habitat utilization and habitat requirements of jaguars at the northern limit of their range. This JAG Team Scientific Advisory Group has identified that the highest priority for jaguar work in the borderlands region is to radio collar at least one individual to collect detailed information on jaguar habitat use and movement patterns (O'Neill and Van Pelt 2004). Between 2001 and 2005, the Borderlands Jaguar Detection Project has used trail cameras and track/scat surveys to document at least two, and possibly three, different jaguars currently using habitats in southeastern Arizona. The regularity of jaguar detections on this project strongly suggests continued occupancy of jaguars in Southeastern Arizona (McCain and Childs 2006) and invites the opportunity to study jaguar ecology and habitat requirements in the American Southwest.

At the January 2005 JAG Team Meeting in Wilcox Arizona, the topic arose of using GPS telemetry on one or more of the jaguars that were, at that time, being photographed with regularity in a mountain range of southeastern Arizona. This discussion stirred a debate concerning the ethics of radio telemetry and the potential risks of capture and immobilization to the health and welfare of the jaguar and the personnel involved. On 26 January 2005 the Depredation Committee of the JAG Team held a risk assessment meeting to determine the safest and most effective methods of capturing and handling jaguars given the local conditions. A report from that meeting, "Risk Assessment of the Methods Available to Capture, Tranquilize and Radio Collar Jaguars in Southern Arizona" was submitted to the JAG Team by Jack Childs, Chairman of the Depredation Committee (Childs 2005). However, the JAG Team again received considerable objection to the capture and collaring of a jaguar from several groups and individual citizens in attendance at the JAG Team meetings, such as Sky Island Alliance, Defenders of Wildlife, and Center for Biological Diversity. As a result, several noninvasive research alternatives were proposed and discussed at the August 2005 JAG Team meeting in Douglas, Arizona. The effectiveness of these methods remains questionable in their ability to provide adequate scientific information in the timely fashion necessary to guide the JAG Team in applying appropriate conservation management for this species.

As a result of these debates (to capture or not to capture, to use state-of-the-art GPS telemetry or DNA extracted from scat samples, to use trail cameras or hair snares, etc.) the JAG Team decided to revisit and redefine the research objectives of the JAG Team before deciding upon the appropriate method(s) to be used. Until this point there has not been a clear understanding or agreement among the JAG Team on exactly what types of information are needed to effectively guide responsible and informed jaguar conservation. Therefore, it must be determined what we need to learn about the jaguar before we decide just how we will achieve those objectives.

The purpose of the Research Committee and this report are to define the research objectives of the JAG Team and determine how to achieve those objectives. This committee will oversee the research activities of the JAG Team, and strive to gather the information that is most needed to drive successful conservation management for the jaguar in the United States. On September 16, 2005 the first Research Committee meeting was held at the Arizona Game and Fish Department Region 5 office in Tucson, Arizona. This meeting called together local researchers and biologists with experience, expertise and involvement in this or other closely related research-based conservation efforts. In attendance were: Jack Childs, Chairman Depredation Committee/ Borderlands Jaguar Detection Project; Anna Mary Childs, Borderlands Jaguar Detection Project; Matt Colvin, Depredation Committee/ Borderlands Jaguar Detection Project; Don Swann, Saguaro National Park; Lisa Haynes, University of Arizona/ independent researcher; Kevin Hansen, Southwest Wildlife Foundation/ biologist and author; and Emil McCain, biologist Humboldt State University/ Borderlands Jaguar Detection Project. The identified research objectives were approved by the JAG Team at the 19 January 2006 meeting. The next Research Committee meeting was held on 27 January 2006, at which time the methodology and study design were outlined. The same committee members attended this meeting with the addition of Tim Snow, non-game biologist Arizona Game and Fish Department. The committee will oversee research activities of the JAG Team and will be advised by the Scientific Advisory Group, the Habitat Committee, and the Depredation Committee.

RESEARCH OBJECTIVES

We have identified the following research objectives regarding jaguar habitat utilization in southeastern Arizona and southwestern New Mexico as the focus of future research efforts of the Arizona/New Mexico Jaguar Conservation Team.

1.) Describe and quantify the current distribution of jaguars in Southeastern Arizona and Southwestern New Mexico. (First-order selection)

2.) Describe and quantify the habitat requirements of jaguars in Southeastern Arizona and Southwestern New Mexico. (Second and Third-order selection)

Central to modern wildlife studies and wildlife management is the study of species habitat selection. The definition of habitat selection presented by Johnson (1980) and later redefined by Thomas and Taylor (1990) involves researching an animal's use of habitat types in comparison to the availability of all habitats in the animal's environment. When an animal uses a specific resource (e.g. food item or vegetation type) out of proportion to the availability of that resource, the animal is exhibiting habitat selection (Johnson 1980, Thomas and Taylor 1990). Studies investigating habitat selection are designed to measure the use versus availability of different habitats or habitat types. However, challenges often lie in determining the scale at which habitats are defined and measured (e.g. how large is the area and what habitats are actually "available" to a particular species). In the seminal papers that redefined the science of wildlife habitat selection, Johnson (1980) and Thomas and Taylor (1990) identified three different spatial scales. These show how habitat selection can be studied for wildlife species in which animals make decisions about resource use at hierarchical stages. After reviewing 54 papers that addressed habitat selection, these authors classified three basic designs of habitat studies.

First-order selection studies estimate all resource use and availability for all animals within a broad regional study area. These studies often compare the relative number of animals or their sign (tracks and scats) observed in each habitat type during surveys to the proportion of the respective habitat types in the study area. Individuals are not identified, so use and availability measures are made at the population level. In Second-order selection, the use of each resource is measured for each individual animal. The relative number of relocations of a known individual in each habitat type is compared to the proportion of the study area comprised of the respective habitat types. This method is often used to address habitat selection of a species by comparing habitat utilization by an individual (home range or territory) to the habitat availability within the entire study area. Third-order selection studies examine home range or territory of an individual and compare habitat use and availability within that area (see Thomas and Taylor 1990 for more detailed information). The three designs or levels of habitat selection studies basically incorporate three different spatial scales in which the habitat selection can be studied. At a large scale, first-order selection studies estimate species distribution over a regional geographic study area. Second-order selection studies examine habitat utilization within the species' range of distribution and third-order selection studies investigate specific resource selection within occupied home ranges or territories. Habitat selection information at these different spatial scales are critical to the ecologically sound management of wildlife species and their native habitats (Thomas and Taylor 1990).

Remote photography enables the study of phenomena that are difficult to address through traditional methods of observation. Remotely triggered trail cameras have been used to identify species presence and distribution (Kucera et al. 1995, Carrol et al. 1999), identify nest predators (Bayne and Hobson 1997), monitor activity patterns and behavior (Bridges et al. 2004), document use of highway underpasses (Foster and Humphrey 1995), and estimate population densities (Karanth and Nichols 1998b, Carbone et al. 2001, Henschel and Ray 2003). The resulting photographs of elusive species, like jaguars, are impressive and appealing and can be valuable for educational purposes as well as promoting public interest and conservation awareness (Cutler and Swann 1999). Therefore, this technology has become an important tool for the monitoring and conservation of rare, cryptic species in a wide range of environments, including tigers (*Panthera tigris*), leopards(*Panthera pardus*), and jaguars (Carbone et al. 2001, Henschel and Ray 2003, Silver et al. 2004). In reviewing the use of remotely triggered trail cameras in wildlife ecology studies, Cutler and Swann (1999) found that of 107 studies research objectives include: nest predation (21%), feeding ecology (18%), nesting behavior (18%) and the description or evaluation of remote photography equipment (18%). The use of remote photography was less common in the study of activity patterns (12%), population parameters (7%), and to detect the presence of a species (6%).

Due to the constraints of these noninvasive presence/absence surveys, these methods are insufficient by themselves in describing detailed habitat selection for such a large, wide-ranging carnivore as the jaguar (Thomas and Taylor 1990). Unfortunately, the nature of most noninvasive survey techniques leaves them with the shortcomings of seriously biased sampling, as surveys are conducted in "the most probable locations" to obtain results (i.e. surveys are conducted where the researcher believes there is the greatest probability of detecting the target species) (Henschel and Ray 2003). True habitat selection studies, however, require a sampling regime that surveys all available habitats and can then compare the habitats that the animal used to those habitats available (Thomas and Taylor 1990). In reality, the current noninvasive presence/absence surveys cannot thoroughly sample all habitats that are available to the jaguar and sufficiently cover the amount of ground that a jaguar can cover. Therefore, the resulting data cannot adequately address the issue of habitat selection. We cannot know that an animal does or does not use a particular habitat if we do not look for that animal in that habitat. It is unrealistic to cover every inch of southeastern Arizona and southwestern New Mexico with noninvasive camera traps and track/scat transects.

Recently, sophisticated models have been developed to systematically survey for species that can be individually identified, like tigers and leopards (Henschel and Ray 2003), and several species in which individuals cannot be distinguished by external markings, like fisher (*Martes pennanti*) and marten (*Martes americana*) (Zielinski and Stauffer 1996, Carrol et al. 1999, Carbone et al. 2001). These models involve high powered statistical analysis using capture/recapture data to estimate species abundance and density. Densities can be compared between different areas (Silver et al. 2004) and inferences can be made to develop habitat models (Carrol et al. 1999). At first glance, these techniques appear ideal for addressing our research needs for jaguars in the United States. However, here at the northern extreme of the jaguar's range we lack the single, most critical component for such studies: a sufficient density of jaguars to obtain a useable sample size for analyses with any statistical power (Henschel and Ray 2003, Silver et al. 2004). The camera surveys of the Borderlands Jaguar Detection Project that have been conducted continuously for the past 5 years have documented jaguars in the region, but at a very low detection rate. This low detection rate is indicative of a jaguar density that is too low to achieve a reliable density estimate, regardless of the amount of camera trapping effort (Karanth and Nichols 1998b, Henschel and Ray 2003). Similarly, the low density and low detection rate limit the usefulness of camera trapping to quantify habitat utilization with any power or detail (Zielinski and Stauffer 1996, Carrol et al. 1999). When detection rates are low, camera traps can be used to document presence and distribution over a large geographic area. In areas with ongoing studies, where several individuals are already identified, distributing cameras throughout the area might deliver supplementary information about the movements of known individuals (Henschel and Ray 2003). Additionally, the noninvasive techniques can shed light on relative abundance of more common species in the area, and yield information on prey species abundance and distribution (Carbone et al. 2001).

In order to accurately describe jaguar habitat for the purpose of conservation management for the jaguar and its habitats in the American Southwest, we must take the next step. We must go beyond presence/absence surveys. We propose a combination of studies to first determine the current status and distribution of jaguars over southeastern Arizona and southwestern New Mexico using noninvasive presence/absence surveys. Once a jaguar is located, we recommend detailed studies on habitat selection and general ecology using a combination of GPS telemetry and noninvasive techniques.

Objective 1.) Describe and quantify the current distribution of jaguars in southeastern Arizona and southwestern New Mexico (First-order selection).

At a broad regional scale we will implement first-order selection studies (Thomas and Taylor 1990) to document jaguar habitat selection over the broad geographical expanse of southeastern Arizona and southwestern New Mexico. Habitat availability will be defined as areas of historical jaguar sightings (Brown and Lopez Gonzales 2001) and from habitat maps generated by the JAG Team's Habitat Subcommittee, the Arizona Game and Fish Department (Hatten et al. 2003), and the New Mexico Game and Fish Department (Menke and Hayes 2003), as well as independent researchers (Boydston and Lopez Gonzales 2005). The borderlands region of southeastern Arizona and southwestern New Mexico contains several remote Sky Island mountain ranges and major north/south river systems containing areas of theoretically suitable jaguar habitat. The first-order selection approach to habitat selection will determine which, if any, of these Sky Island mountain ranges and major river systems are used by jaguars. These surveys will also serve to ground-test the theoretical computer-generated maps discussed above. Studies at this regional scale will determine the current status and distribution of the jaguar throughout southeastern Arizona and southwestern New Mexico and identify individuals coming into the United States from populations in Mexico.

Two adult male jaguars, and a possible third individual, have already been documented in one of the mountain ranges along the border (McCain and Childs 2006). This mountain range is currently being surveyed intensively, with approximately 25 cameras/100 sq miles and an equal density of track/scat transects. There are several more mountain ranges with potential jaguar habitat in southeastern Arizona and southwestern New Mexico that deserve equal attention. We recommend expanding the existing research geographically to encompass all potential jaguar habitat in southeastern Arizona and southwestern New Mexico.

Objective 2.) Describe and quantify the habitat requirements of jaguars in southeastern Arizona and southwestern New Mexico. (Second and Third-order selection)

Once a jaguar is detected within the study area, we will study specific habitat utilization of that jaguar in more detail. We will increase the quantity and quality of information gathered by studying jaguar habitat selection at the finer spatial scales characterized by Johnson (1980) and Thomas and Taylor (1990) in their second-order and third-order habitat selection studies. Unlike first-order selection, these studies will not only tell us that jaguars use a particular mountain range, but we will learn the full extent of where jaguars are traveling, what parts of the habitat they are using, what they eat and how much space they need. Second-order and third-order habitat selection studies yield detailed information about the specific utilization of different habitat types within the area that a species or group of individuals occupy. The resulting data facilitate improved conservation management for the species and its habitats (Beier et al. 1995, Dickson and Beier 2002).

The more detailed information generated in second and third-order selection studies is critical to the proactive and adaptive conservation of a sensitive species like the jaguar. Jaguars are elusive and far-ranging carnivores about which very little is known in this environment. Without detailed habitat studies, conservation efforts would be based on unsubstantiated guesswork. When individual animals are identified, which is necessary in second and third-order selection studies; they can be closely tracked over space and time. This facilitates the identification of home ranges, habitat utilization, travel routes, predation habits (Schaller and Crawshaw 1980, Rabinowitz and Nottingham 1986, Crawshaw and Quigley 1991, Dickson and Beier 2002) and even seasonal fluctuations in utilization of habitat attributes (Crawshaw and Quigley 1991, Beier et al. 1995). We will be able to identify the size and composition of habitats that comprise core habitat. These studies will illustrate the vegetation types and topography used by jaguars in this environment. We will identify major travel routes and connections between areas of core habitat (Beier 1993, Beier et al. 1995). We will be able to closely monitor jaguars for potential jaguar/livestock conflicts or even jaguar/human conflicts. In the event of conflicts, we will be able to analyze the circumstances and hope to adaptively manage future situations (Polisar et al. 2003, Treves and Karanth 2003).

It is possible that closely following an individual will lead us to other jaguars and other jaguar habitats that are currently unknown. If there is another jaguar in the vicinity, a collared jaguar will likely know this and may lead researchers to it (especially if it is a male looking for a female). This possibility of a larger sample size would potentially allow studies to examine connectivity to other jaguars and jaguar populations as well as connectivity to currently unoccupied areas of core habitat containing adequate resource attributes to support jaguars. Theoretically, once more individuals are located, social structure and social dynamics can be studied, including interactions between individual jaguars (Pierce et al. 2000) and between jaguars and other sympatric species such as the mountain lion (*Puma concolor*), bobcat (*Lynx rufus*) and black bear (*Ursus americanus*) (Emmons 1987, Polisar et al. 2003, Scognamillo et al. 2003, Novack et al. 2005). Most importantly these studies will alert us to when and where areas of core habitat, connectivity between core areas, or other important habitat attributes are being threatened. This will give us the opportunity to respond promptly with the necessary intervention. This type of detailed information is much needed by wildlife managers to successfully manage for jaguar conservation in today's dynamic political and economic environment of the borderlands region (Quigley and Crawshaw 1992, Dickson and Beier 2002, Polisar et al. 2003, Treves and Karanth 2003).

STUDY SITE

The study will include the mountain ranges and major riparian areas in southeastern Arizona and southwestern New Mexico, running from the eastern boundary of the Tohono O'Odoom Indian Reservation at the crest of the Baboquivari Mountains east to the eastern boundary of the Gray Ranch in New Mexico. The study area encompasses portions of the Coronado National Forest, the Buenos Aires National Wildlife Refuge, Fort Huachuca Military Base, lands managed by the Bureau of Land Management, and several private ranches. Survey efforts will be concentrated in the areas of historic jaguar sightings and the habitats identified by the Habitat Committee of the JAG Team. The vegetation of the area is typical of the Madrean evergreen woodland of the upper Sonoran Desert. The oak woodland-oak grassland community is the dominant vegetation type between 1100m and 2000m. Below 1100m, mesquite-Sonoran desert scrub predominates.

OUTLINE OF METHODOLOGY

Objective 1: Describe and quantify the current distribution of jaguars in southeastern Arizona and southwestern New Mexico.

To determine the current distribution of jaguars in southeastern Arizona and southwestern New Mexico a combination of noninvasive techniques will be used to conduct presence/absence surveys over the regional study area of southeastern Arizona and southwestern New Mexico.

> Method 1: Camera traps located in Sky Island mountain ranges of southeastern Arizona and southwestern New Mexico. Camera sites to be located along the most likely travel routes of large felids. Sites to be determined by experienced researchers with a background in large felid research.

Method 2: Scat collection utilizing trained scat-detecting dogs. To be carried out along the most likely travel routes within the Sky Island mountain ranges and along major north/south river drainages using a grid pattern as permitted by terrain features. Sites to be determined by experienced researchers with a background in large felid research. Samples to be analyzed to determine species using mitochondrial DNA, specifically cytochrome B.

Method 3: Track surveys to be conducted in conjunction with methods 1 and 2 in areas where substrate is conducive to detect tracks. Tracks to be documented using photography, measurements, tracing, and when possible, plaster casts. Tracks will be identified to species using the criteria of Childs (1998) and other tracking guides.

Method 4: Volunteer outreach program utilizing local land owners and citizens to monitor camera traps, conduct track surveys and collect scats. Volunteers for this method must complete a training course conducted by experienced felid researchers that will consist of both classroom study and field trips into areas of surveillance.

Method 5: Investigate potential jaguar sighting reports using Arizona Game and Fish Department and New Mexico Game and Fish Department personnel and individuals having completed training classes described in method 4. Methods 1, 2, and 3 will be used in conjunction with the established jaguar sighting questionnaire to follow up on jaguar sightings. (Jaguar Sighting Report, Check List for Suspected Predator Kill Document and Track Documentation Guide) (Appendices IV and VIII in O'Neill and Van Pelt (2004)).

Note: These methods are designed solely to document jaguar presence in southeastern Arizona and southwestern New Mexico. If or when a jaguar or jaguars are located, the methods listed under Objective 2 should be initiated as soon as possible in the geographical areas with confirmed jaguar detections.

Objective 2: Describe and quantify the habitat requirements of jaguars in southeastern Arizona and southwestern New Mexico.

To determine specific jaguar habitat selection and utilization, a combination of noninvasive and invasive techniques will be used to study the jaguars located in Objective 1. Due to the efficiency of modern GPS telemetry in collecting complete and accurate information in a timely and cost efficient manner, the Research Committee recommends the use of GPS telemetry, in addition to concentrated noninvasive study techniques. The committee acknowledges the sensitivity of jaguar capture and advises strict precautions be taken during capture. We highly recommend that all live-capture activities follow the protocols in the Wildlife Conservation Society’s Jaguar Health Program Manual (Deem and Karesh 2002). These were established from years of collaborative experiences throughout the jaguar’s range to provide a standard for the safety of the biologist and the safety and welfare of the animal. This manual explicitly outlines all aspects of handling immobilized jaguars and trouble shooting anesthetic emergencies. We recommend that the jaguar capture protocol established by the Jaguar Conservation Team in 1997 (appendix II and III in O'Neill and Van Pelt (2004)) be updated and standardized with the Wildlife Conservation Society's protocol and updated again every 6 months thereafter. The capture team personnel need to be selected and updated on these protocols. The Research Committee recommends the use of trained hounds and hunters employed by USDA-Wildlife Services in Arizona and New Mexico to be the preferred method of capture (Childs 2005). The Research Committee also recommends hiring a professional field biologist with recent experience in the capture and tranquilizing of jaguars for the immobilization and all handling of jaguars during the capture and in the process of attaching a GPS transmitting collar on the jaguar. Provided these criteria can be met, the Research Committee recommends the following studies.

Method 1: Physiological measurements and tissue collection during capture for complete genetic profile and physical assessment.

Method 2: GPS telemetry to be used to delineate home ranges and determine habitat selection.

Method 3: Ground telemetry and on-the-ground follow-up of GPS telemetry locations to be used to document specific habitat use and daily activities.

Method 4: Camera traps to be concentrated in identified area and used in paired sets to enable individual identification for mark-recapture techniques. Camera sites to be determined by experienced researchers with a background in large felid research.

Method 5: Scat collection utilizing trained scat-detecting dogs and using a grid pattern system as permitted by terrain features. Samples to be analyzed first using mitochondrial DNA to confirm species and then using nuclear DNA to determine gender (presence or absence of a gene in the Y chromosome), individual identification (using a set of 6-12 microsatellites) and relatedness between individuals and populations (using sets of microsatellites).

STUDY DESIGN

Objective 1.

Method 1. Trail Camera Stations

Trail cameras will be used in a systematic survey of all Sky Island mountain ranges of southeastern Arizona and southwestern New Mexico that contain potentially suitable jaguar habitat (Menke and Hayes 2003, Boydston and Lopez Gonzales 2005, Hatten et al. 2005). The systematic surveys recommended for large cat distribution studies use grid cells that must be smaller than minimum home range area of the target species (Henschel and Ray 2003). In this case the home range size remains unknown; however, since grid size also influences the resolution of the data, we will maintain relatively small grids for more detailed data and higher detection probability. A 5000 m by 5000 m grid will be generated over the study area. At least one camera trap will be placed along the most probable travel route(s) within each 25 square km grid. Cameras will be located at distances greater than 1km apart along washes, trails, dirt roads, ridges and canyon bottoms and major mammalian travel routes (Karanth 1995, Karanth and Nichols 1998a, Henschel and Ray 2003, Novack 2003) and in areas where travel by wildlife is naturally directed or funneled by landscape features. Exact camera locations will be determined by sign present (tracks and scat) as well as the existing knowledge of the local landowners, ranchers, hunters and biologists (Henschel and Ray 2003, Wallace et al. 2003). In some places, undefined or wide trails, travel paths and washes may be funneled by manipulating existing vegetation and/or micro-landscape features to concentrate mammalian traffic within range of the camera.

Digital trail camera systems designed for continuous surveillance of medium to large mammals will be used for this study (Cuddeback Digital® – Non Typical Inc. Park Falls Wisconsin). These are fully automatic digital cameras combined with a passive infrared motion detector that senses heat-in-motion within a conical area. The fully enclosed, weatherproof unit is aimed across established travel routes and silently takes a photograph of any warm-blooded animal that moves across the targeted space. The camera unit is locked inside a protective metal box that attaches to a tree at approximately 0.3 m above the level of the trail or travel route. The exact time and date is recorded on each photograph as well as the camera site information (location, name or number).

Each camera will contain a removable compact flash card with 256 MG of storage space. The 3.0 MegaPixels cameras will store up to 512 images and monitor continuously for up to eight weeks. Cameras will be programmed to monitor activity 24 hours a day and will take photographs as often as once per minute as long as activity is detected. Cameras will be checked every six to eight weeks to replace batteries and recover the flash card. Each flash card will be downloaded to a storage database and viewed to record the species and time stamp yielding the time and date for each frame or detection.

Camera surveillance will be conducted in the Sky Island mountain ranges only and not in the broad flat valley bottoms of the major river systems. Camera traps were considered for these areas, and it was decided that it would be extremely difficult, if not impossible to predict travel routes for large carnivores in broad flat to rolling valleys. A grid of camera traps in these areas was also considered, but due to cost and logistics of such an undertaking, it was decided that it was necessary to first have some evidence that the target species used these areas. These areas will be sampled on a grid using the techniques described below. (See scat collection and track survey methods below)

Method 2: Scat collection

Scat surveys will be conducted within the Sky Island mountain ranges and along major north/south river drainages. Trained scat-detecting dogs can be utilized to assist in scat surveys of these areas (Wasser 2005). Hornocker (1970) and Seidensticker et al (1973) found that fecal marking served as important chemical communication in mountain lions, and scats tended to be located along major travel routes and territory boundaries. Smith et al. (1989) showed that radio-tagged tigers strategically placed scats and other chemical communicators in areas that channel and concentrate travel. In the mountain ranges, predesignated transects will not be used; rather the entire area will be sampled, concentrating on major travel routes along canyon bottoms, ridge tops, trails, roads and saddles (Hornocker 1970, Seidensticker et al. 1973, Smith et al. 1989). These surveys will be conducted every six to eight weeks in conjunction with monitoring cameras traps in the area. In the major north/south river systems, scat surveys will be conducted using a grid pattern as permitted by local terrain features (Henschel and Ray 2003). These surveys will also be conducted every six to eight weeks. All scats located will be collected with sterile technique and stored in clearly labeled paper bags and frozen until analysis (R. T. Golightly pers. comm. 2004, M. Culver pers. comm. 2005) All scats will be submitted to a genetics laboratory where mitochondrial DNA will be extracted to identify the species of the predator (Farell 2001, Davison et al. 2002, Novack et al. 2005).

Method 3: Track surveys

Track surveys will be conducted in conjunction with methods 1 and 2 in areas where substrate is conducive to detect tracks. Tracks will be identified to species using the criteria of Childs (1998) and other tracking guides and then properly documented using photography, measurements, tracing, and when possible, plaster casts. In the mountain ranges track surveys will be primarily located along sandy wash bottoms in riparian areas, remote roads and trails and around ponds and water holes where tracking conditions permit. These surveys will be conducted every six to eight weeks in conjunction with operating camera stations and conducting scat surveys. In the valley bottoms along major river systems, track surveys will be done together with scat surveys in a standard grid manner as local landscape features permit (Henschel and Ray 2003).

Method 4: Volunteer outreach program

Volunteer groups of local landowners and citizens will be used to assist in monitoring camera traps, conducting track surveys and collecting scats. These volunteers will be trained extensively by experienced researchers appointed by the JAG Team and must complete a training course that will consist of both classroom and field instruction and examinations. The training will include detailed instruction on the processes involved in the three field research methods mentioned above and the completion of the associated datasheets and data entry. The course will emphasize trail camera operation and ways to distinguish jaguar sign and especially jaguar tracks and kills from other predators of the region as illustrated in Childs (1998).

Methods 5: Investigate potential jaguar sightings

Arizona Game and Fish Department and New Mexico Game and Fish Department personal and individuals having completed training classes described in method 4 will investigate all potential jaguar sighting reports and potential jaguar depredation reports. Methods 1, 2, and 3 will be used in conjunction with the documents established by the JAG Team to investigate jaguar sighting reports and suspected jaguar livestock kills. (Jaguar Sighting Report, Check List for Suspected Predator Kill Document and Track Documentation Guide) (Appendices IV and VIII in O'Neill and Van Pelt (2004)).

Note: These methods are designed solely to document jaguar presence in southeastern Arizona and southwestern New Mexico. If or when a jaguar or jaguars are located, the methods listed in Objective 2 should be initiated as soon as possible in the geographical areas with confirmed jaguar detections.

Objective 2.

Animals will be captured by a capture team consisting of 5 people (Cavalcanti 2003): a lead biologist with recent experience immobilizing and handling jaguars, a veterinarian with recent experience working with large felids, a professional agency houndsman with recent experience in local terrain and conditions, an assistant to aid the biologist and an assistant to aid the houndsman. Capture efforts will be made when a jaguar has recently been documented in the area with the methods described in Objective 1. Treed or bayed jaguars will be immobilized with Telozol, or a combination of Telozol and Ketamine hydrochloride, using a dart fired from a CO_2 rifle (see capture protocol (Deem and Karesh 2002)). After the dart is fired, the dogs will be removed from the capture site. The immobilized animal will be placed on a tarp in the shade for processing. The eyes will be covered and ophthalmic ointment will be applied to minimize drying and stress. Noise and movement will be kept to a minimum. The veterinarian will closely monitor the body temperature, pulse, and respiration and take other important measures of the animal's health, to complete the datasheet in Appendix 4 of the Jaguar Health Program Manual (Deem and Karesh 2002). The veterinarian and biologist will examine the animal for general body condition. The biologist and assistant biologist will record data as they sex, age, weigh, measure, and photograph the animal following the Wildlife Conservation Society's protocol (Deem and Karesh 2002) and fit the GPS collar. Once the collar is successfully attached and all measurements are recorded, the entire team will vacate the site except for the lead biologist who will observe the animal until it recovers and leaves the capture site (Cavalcanti 2003).

Method 1: Physiological measurements and tissue collection

At the time of capture and immobilization, the trained veterinarian and capture team will perform physiological measurements and tissue collection from the jaguar for a complete physical assessment and genetic profile. The animals will be weighed and measured, and tissue samples will be collected following the protocol of the Wildlife Conservation Society Jaguar Health Program Manual (Deem and Karesh 2002). Measurements will include body length, tail length, chest girth, head length, head width, head girth, height at shoulder and hip, length and width of each canine, distance between top canines and bottom canines, tooth color and wear, and detailed measurements and photographs of front and rear feet as described in Childs (1998). The animal will be aged using gum-line recession (Laundre et al. 2000) and tooth color and wear (Anderson 2004). Blood, tissue, urine and fecal samples will be collected in a sterile fashion for a complete genetic profile (Culver pers. comm. 2005) and examination for disease and parasites (Waid 1990), hormone levels and stress hormones (Berger et al. 1999, Bonier et al. 2004). The general condition of the animal will be recorded. The animal will be photographed in full to record spot patterns and coloration markings. Any unusual or distinguishing features will also be photographed.

Method 2: GPS telemetry

The jaguar is notoriously difficult to study throughout its range (Schaller and Crawshaw 1980, Rabinowitz and Nottingham 1986, Crawshaw and Quigley 1991). In the northern extent of that range, its secretive nature, low density/scarceness (Brown and Lopez Gonzales 2001), and wide-ranging movements (McCain and Childs 2005 prelim. data) make it very difficult to gain the ecological knowledge necessary to guide effective management strategies. Due to the fortunate opportunity to study free-ranging jaguars currently utilizing areas within southeastern Arizona, the Research Committee advises the most efficient field research possible be conducted to determine detailed habitat utilization and habitat requirements. GPS telemetry provides continuous data collection over extensive areas with a high degree of accuracy and precision (Frair et al. 2004).

The GPS collar chosen as most appropriate to achieve study objectives is the Telonics Gen III GPS collar with ARGOS satellite uplink. These collars record GPS locations (Universal Transverse Mercator, UTM) at predetermined times and then send the most recent six locations through an AGROS satellite uplink directly to the researcher. This uplink data transfer is also programmable, and can be scheduled to transmit at random times to avoid hacker interception of data. Any locations that are not transmitted in the scheduled uplinks will be stored onboard the collar and can be recovered when the collar is removed. We recommend several locations be recorded during both day and night to document day-beds as well as travel/hunting areas and feeding/predation sites respectively. Anderson (2003) programmed collars to attempt locations at 1600, 1900, 2200, 200, 500 and 800 hrs each day to target when cougars were most likely pursuing prey and/or feeding on a carcass.

The current knowledge of activity patterns for the jaguar in this arid environment is limited, but suggests that the majority of movements are made at night and that jaguars rarely move during daylight hours (McCain and Childs 2006 prelim. Data; n=30). For the purposes of determining detailed habitat utilization, we recommend scheduling four locations a day at 000, 400, 1200, and 2000. This sampling regime will allow three locations each night over an eight hour period. This will sample when jaguars are most likely moving, pursuing prey or feeding with one location at midday when jaguars are most likely resting to document day-beds (Schaller and Crawshaw 1980, Beier et al. 1995).

Home range size, habitat use and movement patterns will be documented by locations from the GPS collar. All locations will be loaded into a global information system (GIS; ArcView® 3.2 (ESRI 1999 Redlands, California, USA) and analyzed using the Animal Movements and Tracking Analysis extensions of ArcView. Home ranges will be delineated using minimum convex polygons (MCP's), the adaptive kernel estimator (Worton 1989), and local nearest neighbor convex hulls (Getz and Wilmers 2004). Home ranges will be calculated separately for summer (April-Sept.) and winter (Oct-March) and combined for annual home range estimates (Logan and Sweanor 2001, Dickson and Beier 2002).

Habitat selection will be examined following the compositional analysis described by Dickerson and Beier (2002) quantifying cougar habitat selection in the Santa Ana Mountain Range of Southern California. Habitat use will be examined at the two orders of selection described by Thomas and Taylor (1990). GIS (Global Information System) layers of the different habitat attributes will be used, and the location data points and home-range estimates will be laid over the habitat layers. Habitat attribute layers will include the habitat criteria recommended by the JAG Team Scientific Advisory Group (Hatten et al. 2005) and more detailed local vegetation and topography layers. The "habitat composition" will refer to a vector of proportions of habitat categories (as defined by vegetation type, cover, or other classifying factors) that are used by an animal or available to an animal. This will allow true habitat selection analysis by comparisons of the different habitat attributes that are actually used versus what is available within the study area (Thomas and Taylor Second-order selection) and within jaguar home-ranges (Thomas and Taylor Third-order selection).

<u>Method 3: Ground telemetry and on the ground follow up of GPS telemetry locations</u>

The sampling of GPS telemetry can also allow more detailed examination of habitat aspects at specific sites. GPS locations from collared animals (especially clusters of locations) can be visited on the ground for detailed examination of day-beds, kill sites, and potential interactions. This method of following up on GPS locations is most useful in describing predation habits and estimating predation rates. Predation sites will be identified by clusters of GPS collar locations (Anderson 2003, Sand et al. 2003) when two or more locations are located within <200 m of each other during the same or consecutive 24 hr periods. These sites will be searched for a kill or signs of another jaguar and potential courtship or territorial behavior (Cavalcanti 2003). Location clusters will be located using a hand-held GPS receiver and searched for prey remains, scats or other sign. At predation sites, prey species, age, sex, portions of carcass consumed, scavenger presence, and jaguar sign will be recorded. Jaguar scats will be collected for analysis of diet, DNA, hormones, parasites, and disease. Additionally, at each kill site, measurements of habitat composition can be made on habitat type, vegetation type, cover percent, slope, aspect, elevation, and distance to water.

<u>Method 4: Camera traps</u>

In the areas where the presence of one or more jaguars is documented in Objective 1, a more sophisticated sampling to address habitat utilization will be implemented. The method of "adaptive cluster sampling" was originally developed for tiger studies and is now widely considered most suited to the typical distribution of large carnivores. "This builds on a simple or stratified sampling design by sampling all the cells bordering those where presence was recorded in the initial survey and continuing to do so until the cluster is surrounded by cells that fail to detect presence" (Karanth and Nichols 2002 in (Henschel and Ray 2003)). To increase the resolution or coarseness of the resulting data, each 25 square km grid cell can be divided into four 2.5 km by 2.5 km grid cells of 6.25 square km.

All camera trap sites in this area will be improved to identify each individual jaguar through trail camera photography. This will be accomplished by following the methodology used worldwide in other noninvasive studies of jaguars, (Wallace et al. 2003, Silver et al. 2004) leopards (Henschel and Ray 2003), and tigers (Karanth 1995). Jaguars have unique spot patterns on their coats that can be used like fingerprints to identify individuals. However, for positive identification of a jaguar, it is necessary to acquire photographs from both sides of its body. This is accomplished by doubling up cameras at each monitoring site and placing one camera on either side of a trail or travel route. The result is simultaneous pictures that show the spot patterns on both sides of the jaguar which can be used to positively identify each individual (Karanth and Nichols 1998b, Henschel and Ray 2003, Wallace et al. 2003, Silver et al. 2004).

The identification of individual jaguars at each monitoring station will enable us to follow individuals over space and time for rough estimates of home range size, movement patterns, habitat associations, and potential interactions between individuals. Given a large enough sample size, we could begin to use capture-recapture techniques and statistical modeling to estimate population densities (Karanth and Nichols 1998b, Henschel and Ray 2003, Silver et al. 2004). This would require following mark/recapture model assumptions of population closure (no immigration, emigration, births or deaths during the sampling period (White et al. 1982)) and is extremely unlikely given local conditions.

<u>Method 5: Scat collection</u>

As with the camera trap study above, in areas where jaguar presence is documented in study Objective 1, we will increase the intensity of scat collection in the surrounding areas. A grid pattern system will be established, as permitted by terrain features, and scat-detecting dogs will be used to search that grid on a more frequent basis. The grid system will be laid out to include all major canyon bottoms, ridge systems and trails in the area. Samples will be analyzed first using mitochondrial DNA to confirm species (Farell 2001, Davison et al. 2002, Novack et al. 2005). When jaguar scat is confirmed, it will be further analyzed using nuclear DNA to determine gender (presence or absence of a gene in the Y chromosome), individual identification (using a set of 6-12 microsatellites) (Ernest et al. 2000) and relatedness between individuals and populations (using sets of microsatellites) (Forbes and Hogg 1999, Culver 2005). When an individual is identified by the DNA extracted from scat samples, that individual can be relocated or recaptured when other scat samples yield the same DNA sequence. The identification of individuals using this method can also allow us to track that individual over space and time. Additionally further information can be extracted from the scats to determine the genetic similarity to other jaguars' genetic sequences and thus shed light on the relatedness between individuals or between populations. This information could prove valuable in identifying gene flow, dispersal patterns and potentially the origin of individual jaguars (Forbes and Hogg 1999).This type of data would be critical in identifying important source populations and dispersal corridors critical to jaguar recolonization of its former range in the American Southwest.

All scats that are genetically determined to be from jaguar will be broken apart and sifted to isolate prey remains. Prey remains will be identified to species using dentition, tooth characteristics, claw type, size and shape of hooves (Rosas-Rosas et al. 2003) and macro and microscopic characteristics of the hair (cuticular scales and medulla pattern) (Mayer 1952, Moore et al. 1974). Results will be verified using the reference collections at University of Arizona in Tucson, at Humboldt State University, and Arizona Game and Fish Department.

Food habits will be calculated using the methods developed by Ackerman et. al. (1984) as modified by Cunningham (1999), Navack et al. (2005) and Rosas-Rosas et al. (2003). We will calculate the frequency of occurrence and the percent occurrence of each species consumed. We will then estimate mean biomass consumed of each prey species using the equation: Y = 1.98 + 0.035 X, where Y is the weight of food consumed per scat and X is the total live prey weight (Ackerman et al. 1984). Total live prey weights for local prey species will be obtained from Arizona Game and Fish Department. This approach converts the frequency of occurrence values for each prey species to an estimate of relative biomass consumed and corrects for the overestimations of small prey use from percent of occurrence values (Cunningham et al. 1999, Nunez et al. 2000, Novack 2003, Rosas-Rosas et al. 2003, Novack et al. 2005).

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