Studying Jaguars in the Wild: Past Experiences and Future Perspectives

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Jaguars have been studied in the wild since the late 1970's. However, compared with other large cat species, jaguars are still one of the least known. We describe capture methodologies and study methods used in jaguar research, their application, advantages and disadvantages. Over the years, capture methodologies have improved, primarily in relation to safety measures. Telemetry studies are shifting from VHF to GPS systems with the capacity to collect more information on the species. Among non-invasive methodologies, camera trapping is used to study jaguar density and feces collected with the help of detector dogs can provide information on diet, genetics, health and hormonal status. With improving methodologies and more published information about their applicability, studying jaguars in the wild will hopefully become less challenging.

The first scientific-based information on jaguars in the wild came mainly from anecdotal accounts of hunters in the mid-1970's (Guggisberg 1975; Almeida 1976). Soon after, a research project in the Pantanal investigated jaguar predation on capybaras by examining kills (Schaller & Vasconcelos 1977), followed by radio-telemetry investigations of jaguar movement patterns (Schaller & Crawshaw 1980). Since then, different methodologies have been tested for studying the species in the wild. Still, considering its large distribution, and in comparison to other large cats, little information is available on the jaguar. One of the evident explanations for this lack of knowledge is the difficulty associated with studying the species in its natural environment, considering its generally low population density and cryptic habits. Here, we summarize the methodologies in current use and discuss the future trend for jaguar studies in the wild. The authors cumulatively have experience with all methods described here.

Capturing Jaguars

There are three different techniques to capture jaguars in the wild: trained hounds, snares and live traps with bait. While all three methods are associated with some risk, they have different degrees of success, depending on the study area, field effort, climate, and experience of the capture team.

Capturing with trained hounds

Capturing jaguars with trained hounds is currently the most frequently used capture method. It involves releasing between four and 25 trained hounds on fresh jaguar spoor (Fig. 1). The hounds follow the jaguar scent, chase the jaguar and force it to either tree or stop on the ground (Rabinowitz 1986; Schaller & Crawshaw 1980; Crawshaw & Quigley 1991; Silveira 2004; Soisalo & Cavalcanti 2006; McBride Jr. & McBride 2007; Azevedo & Murray 2007). Tree climbing when being followed by hounds was observed by the Jaguar Conservation Fund (JCF) in 74.4% of 43 jaguars captured in the Pantanal, Cerrado and Amazon. A short or long-range dart projector is used to dart the animal, preferably at the proximal region of the rear limb. After the jaguar has been darted, the dogs are leashed to reduce stress to the jaguar and allow it to descend from the tree before sedation takes effect. In JCF studies, 18.75% of jaguars that climbed a tree upon being chased by hounds descended from it after being darted. If the jaguar moves off, the hounds are released to lead researchers to the immobilized cat. If the jaguar stays in the tree after being darted, a capture net is set up to avoid traumatic falls and a "bed" of leaves is made below the net to prevent the animal from hitting the ground. However, if the jaguar becomes aneasthetized in the tree, a team member should be prepared to climb the tree, tie a rope to the animal's chest and lower it to the ground (Fig. 2). This procedure was necessary in 10% of the cases a jaguar was treed in JCF studies.

The use of hounds assures some selectivity in the capture, as the dogs are trained to track only animals previously identified by their tracks. This assures the researchers that jaguars and not pumas (*Puma concolor*) and adults, not cubs, are tracked. It is also an efficient method. Of the 43 successful captures undertaken by the authors, on average the target animal was aneasthetized after only one hour of tracking, and at a mean distance of 1.8 km from the hounds' release site. However, hounds used to capture jaguars should be experienced, obedient and well trained to chase only the target species. Although efficient, the method does offer some risks to all parties involved. For instance, the falling of an anesthetized jaguar from a tree can result in traumatic injuries of the animal. To avoid this some authors recommend not to dart a jaguar more than 5 meters up in a tree (Deem & Karesh 2005), but the risk of falling even from low or moderate heights still involves

Fig. 1. Jaguar Conservation Fund hounds being led to fresh tracks of a jaguar in the Pantanal (Photo by Jaguar Conservation Fund/Instituto Onça-Pintada).

the possibility of injury or death (McCown 1990; JCF unpublished data). While a capture net placed directly underneath the animal greatly reduces the risk of injuries, people setting the net have to get dangerously close to the jaguar. Also, setting the net may take from 10 to 15 minutes, enough time for the jaguar to jump to another branch or tree. Finally, it is important to consider that hunting of jaguars is prohibited in most of the jaguars' range countries and the contracting of hunters and hounds violates legal and ethical principles. For trained hounds and handlers to be a capturing option, the researcher should hire experienced staff with hounds from existing scientific research or from countries where hunting is permitted.

Snaring jaguar

Leg-hold snares modified for research have been used to catch various large cats (Logan *et al.* 1999; Goodrich *et al.* 2001; McCarthy *et al.* 2005). A leg-hold snare consists of a ¼ inch thick stainless steel cable forming a loop that will close around the animal's foot when it steps on the trigger. The snare cable is attached to an anchor cable through a swivel that allows the captured animal to rotate freely – this swivel is critical to prevent injury. The snare loop has a one-way lock that prevents the loop from loosening. To avoid injuries, a slide stop is been added to the cable to prevent the loop from closing too tightly and cutting off circulation in the foot. The stop can be adjusted for the target species, allowing smaller non-target species to easily escape. A bungee cord and metal coil spring inserted in parallel in the cable work very well as shock absorbers. Snares can be set along trails, drainages, places where cat spoor are frequently found, or around kills and carcasses which function as bait. The success of the snares can be enhanced with a "caller," an MP3 player, with amplifier and speaker, that is programmed to continuously play recordings that may attract the cats and is hidden between two snares. Setting places should be carefully selected to avoid potential dangers for the trapped animal and the researches later trying to release it (e.g. sharp rocks, steep terrain, flash floods, sites too exposed to the sun, etc; Logan *et al.* 1999; Logan & Sweanor 2001). With snares and callers combined, the WWF AREAS-Amazonia study of jaguars in the Peruvian Amazon caught 17 jaguars in the Amazon of southeastern Peru (Fig. 2). No serious injuries or deaths caused by the snares were observed, only swollen paws and minor cuts. There are several methods that help avoid capturing non-target species. A branch can be placed above the snare to deflect ungulates. The trigger can be supported by either a firm sponge or three short pieces of metal strips from a measuring tape to insure that lighter mammals or birds cannot set it off. Still, snares should not be set at places frequently used by non-target species. One of the most important ways to avoid injuries is to check the traps at an appropriate frequency. Checking snares more than once per day and/or constant monitoring with some kind of device like VHF collars/radio transmitters (Logan, pers comm., Nolan 1984; Halstead 1995) is highly recommended. A further recommendation is to close traps when climate conditions are adverse and might cause hypothermia or overheating to the trapped animal (Powell & Proulx 2005). While there will always be a potential for injury or even death, with proper use, snares have generally proven to be an efficient method to capture large cats.

Live Traps

Cage traps baited with live animals (e.g., domestic pig or sheep) can be placed along natural trails, transect or roads (Rabinowitz 1986; Morato *et al.* 2002; Azevedo & Murray 2007). The trap may or may not allow the animal to have access to the bait. Jaguar trap dimension should be of approximate 0.90m x 0.90m x 2.0m with a strong enough welded wire mesh able to constrain the animal inside until it isis anesthetized. Traps must be checked at least once per day to guarantee the captured animals' well-being. Also, the bait requires that food and water be regularly replaced. Traps must be set in the shade to avoid exposition of the bait or trapped animal to the sun.

Captured jaguars inside cages can be very aggressive and inflict serious injury to themselves by biting and hitting the cage (Fig. 4). The most common injury is teeth breakage (Rabinowitz 1987). To avoid this risk, traps should not be made with grating, should not allow the animal to get caught in any parts or dispose loose hard pieces that can be bitten or chewed by the cat. If left in the cage to recover after anesthesia, the animal can be aggressive and cause harm to itself, and there should be caution during release as the cat can turn back to a unprotected person instead of fleeing from the scene. Alternatively, the animal can be placed in a quiet, padded and protected area to recover and leave the site. Risks are involved with both recovery situation as even outside of the trap the jaguar can injure itself by falling, banging itself or drowning in a water puddle while not fully recovered. It is important to remember that with this methodology it can take a longer trapping effort to achieve a capture. The method also involves the risks of capturing non-target species. Another limitation to the use of this method is the expense: steel trap costs, along with transportation and operational costs of feeding the live bait and checking the trap, can become very high.

GPS (Tracktag) versus VHF telemetry for tracking jaguars

While radiotelemetry is in general an excellent technique for determining jaguar home range size (Fig. 5), habitat use, movement patterns, and other spatial attributes (see Schaller & Crawshaw 1980; Rabinowitz & Nottingham 1986; Crawshaw 1995), its effectiveness in dense habitat such as the Amazon forest may be limited. The dense canopy of tropical forests reduces the range of radio signals to a few kilometers at best and ground accessibility is usually limited. The only viable large scale monitoring alternative is the use of small fixed-winged aircraft. This approach is limited to diurnal monitoring and tends to be very expensive. Additional problems associated with radiotelemetry are triangulation errors caused by low accuracy of the reading, bouncing signals or moving animals, as well as a bias of collected data towards more accessible areas. There is also a trade-off between the number of locations that can be collected for each individual and the number of individuals that can be monitored. Therefore, GPS collars have become popular for studying large cats (Anderson & Lindzey 2003; Hemson *et al.* 2005, McCarthy *et al.* 2005) and have been employed successfully in jaguar studies in the Atlantic Forest (Cullen *et al.* 2005; Cullen 2006), Pantanal (Soisalo & Cavalcanti 2006) and the Paraguayan Chaco (McBride & McBride 2007).

Fig. 2. During captures with hounds, jaguars may become aneasthetized up in the tree they seek refuge in. In these cases it is necessary to lower the animal down with a rope (Photo Jaguar Conservation Fund/Instituto Onça-Pintada).

In late 2007, the World Wildlife Fund - US fitted four jaguars in the Amazon of southeastern Peru, with a new type of GPS system called TrackTag (NAVSYS Limited, West Lothian, UK). The TrackTag is an archival GPS unit with a capacity to store up to 30,000 locations in its on-board memory, adapted to fit on a VHF radio-collar. The tag has very low power requirements and its own light-weight energy source. Currently the tag must be retrieved and connected to a computer for data downloading and processing. However, the unit is currently being redesigned to include remote downloading capacity. Like other GPS collars, the unit can be set to collect locations at determined time intervals and can also be equipped with a timed drop-off mechanism. To date, the authors have recovered and processed five collars. Those collars recorded between 662 and 4,250 locations during 3.8 to 7 months that they collected data. This is between 10 to 100 times more data than would typically be collected from a VHF-based study. Cullen (2006) reported five to 15 times more data collected with regular GPS than with VHF collars, depending on density of forest cover.

Although the initial costs of the GPS collars were ten times the cost of a typical VHF collar, the quantity and quality of data collected far outweighs the added cost of purchase as they are more precise and unbiased by time of day or ease of access. While VHF collars are still useful for some studies where infrequent locations are needed, such as monitoring problem cats or reintroduced or translocated individuals, most studies interested in collecting detailed data on the ecology of jaguars should probably consider using GPS collars. For relatively open areas a large num-

Fig. 3. Jaguar trapped on a snare by its front paw in the Peruvian Amazon (Photo S. Carillo-Percastegui).

ber of different models are currently available; from simple store-on-board units, to units that automatically transmit data through a satellite or cell phone connection. For densely forested areas the TrackTags are a viable GPS option, and new more sensitive designs are currently being tested.

Camera traps for estimating jaguar density

Camera trapping to estimate large felid density was initially developed for tigers (Karanth 1995, Karanth & Nichols 1998), but was soon adopted for jaguar studies (Wallace *et al*. 2003), and has since been implemented throughout the species' range (Maffei *et al*. 2004; Silveira 2004, Silver *et al*. 2004, Cullen *et al*. 2005, Soisalo & Cavalcanti 2006, Salom-Perez *et al*. 2007). Camera trapping takes advantage of the unique spot (or stripe) pattern on each cat that permits individual identification of registered animals (Fig. 4). The information on photographic captures and recaptures of the different individuals can be analyzed with capture-recapture models to estimate abundance, which can be translated into a density estimate, dividing abundance by the sampled area. The study design has to consider two model assumptions: 1) All animals within the sampled area have a capture probability larger than 0, thus, cameras must be placed so that there are no internal gaps that could contain an individual's entire home range; and 2) The population under study is closed, i.e. during sampling, no losses or recruitments occur, so a maximum sampling period of two to three months is recommended (Silver 2004). When calculating the sampled area, a buffer around the outer camera trap polygon has to be considered, as portions of the home ranges of registered animals will be located outside of this polygon (Karanth & Nichols 1998). Estimates of buffer width can be obtained in various ways, and as density estimates are sensitive to buffer width, this is subject of ongoing discussion (e.g. Soisalo & Cavalcanti 2006).

Jaguars occur at low densities and consequently, large areas (several hundred km²) have to be sampled with a large number of camera traps (from 25 upwards) to guarantee sufficient data, both in number of individuals captured and in number of recaptures (Karanth & Nichols 2002), making these studies quite expensive (Maffei *et al*. 2004, Soisalo & Cavalcanti 2006) and work intensive. In tropical, open-habitat study areas, camera traps with passive heat-in-motion sensors are likely to be triggered frequently by direct sunlight or even daytime heat. Depending on the model, camera traps can produce more than 50% of pictures of hot air. This increases material costs and creates the need to check cameras more frequently to avoid sampling gaps. Due to financial and logistic constraints, under these conditions researchers may have to confine sampling to night time hours.

Even when functioning properly, only a small fraction of pictures will be of the target species, between 5% and 25% depending on study area, with success rates of two to four jaguar registers per 100 trap nights. To optimize success, traps need to be set at locations with a high probability of jaguar movement, such as roads or trails (Silver *et al*. 2004). This can conflict with the need to cover the entire sampled area without internal gaps, in which case additional trails may have to be opened. Depending on their accessibility, these trails increase time spent checking traps disproportionately. While Silver *et al*. (2004) found manmade trails to work well, the Jaguar Conservation Fund observed low to no jaguar camera trapping success on such trails (JCF, unpublished data). Salom-Perez *et al*. (2007) suggested that differences in use of manmade trails existed between the sexes due to females being more timid. Several studies report a sex ratio of detected animals skewed towards males (Wallace *et al*. 2003; Silver *et al*. 2004; Salom-Perez *et al*. 2007), owing to the females' smaller home ranges and less movement, rather than an actual skewed sex ratio in the population.

Still, the advantages outweigh the drawbacks: Camera traps are non-invasive, can sample large areas continuously, and collect enough data for a reasonable density estimate within two to three months. Some of the drawbacks mentioned can be compensated, at least partially, with site specific sampling designs and choice of the right equipment. In terms of data analysis, capture-recapture models provide a sound statistical basis for density estimation, and data can also be used to investigate jaguar activity pattern and spatial distribution. Recently developed spatially explicit capture-recapture models that estimate density directly without the need to determine the size of the sampled area (Borchers & Efford 2008) hold the potential for more flexible sampling designs and more accurate density estimates. Furthermore, with constant advances in the field of digital photography, a robust, battery-economic digital camera trap should not be too far away.

Using Scat Detector Dogs to Study and Monitor Jaguars

The use of scat-detection dogs is increasingly recognized as a valuable wildlife assessment and monitoring tool (Long *et al*. 2007a). Chosen for their drive for play-reward with a tennis ball, these dogs enable researchers to seek out scat samples of rare and otherwise difficult-to-study species (Fig. 6). The dogs are able to cover large areas, are non-biased in their sampling of gender, and have demonstrated accuracy in their ability to hone in on their targets while ignoring non-target species (Smith *et al*. 2003). In comparison with camera traps and hair snag survey methods, detection dogs have demonstrated superior effectiveness at locating species presence as well as number of individuals (Wasser *et al*. 2004; Harrison 2006; Long *et al*. 2007b). Scat samples can be used to understand wildlife movement, for diet and disease studies, as well as for DNA and hormone analyses (Wasser *et al*. 2004).

Scat detector dogs offer a valuable tool for non-invasive study of jaguar. In a study at Emas National Park (ENP) and surroundings in central Brazil (Vynne *et al.* 2007), scat dog teams were employed over 12 months between 2004 and 2008 for a five species survey including jaguars. Of all putative jaguar samples (n=49), 80% were found off of roads or major trails, and thus would not have been encountered by human search teams alone. We found evidence of jaguar using open, grassland-dominant habitats bordering the agricultural matrix where jaguar had not previously been recorded.

While scat dogs may be the most effective survey method available for detecting presence of elusive species, the required field time is extensive as compared to other methods (Harrison 2006). This is likely to be even more exaggerated for the very wide-ranging jaguars. In the ENP study, we spent approximately 22 hours in the field for every putative jaguar scat encountered.

Fig. 4. Jaguar captured in Emas National Park, central Brazil with a cage trap baited with a live pig. Note that the cage is not properly designed. The jaguar should not have access to the cage bars as they may allow the animal to bite and injure itself. A metal mesh over the bars is recommended to prevent injuries (Photo Jaguar Conservation Fund/Instituto Onça-Pintada).

When jaguars are targeted as the focal species or sampling is restricted to known jaguar niche habitat, detection rates are expected to climb. For example, 90% (n=44 of 49) of the samples were found within the jaguar niche, realized by Silveira (2004) during a radio-collaring study. If we consider only survey days spent in the defined niche, we had an 88% probability of detecting a jaguar on a given field day. Studies in Cantão State Park (Amazon-Cerrado ecotone) and on a private reserve in the Pantanal, where jaguar densities are much higher and where dogs were trained only on jaguar and puma resulted in a much lower search time of about 1.3 hrs per putative large cat scat (Almeida *et al*. 2008).

Well-trained scat dog teams have a demonstrated high accuracy of honing in on target species from 93% to 100% (Smith *et al*. 2003; Vynne, unpublished data; Wasser *et al*., unpublished data). However, inexperienced handlers may inadvertently train dogs onto non-target species by misidentifying scat samples in the field and/or rewarding errantly interpreted dog search behavior. In our study, two experienced dog-handler teams had an 81% accuracy rate of collection for jaguar and puma scats, while a new handler-dog team collected 50% as non-target species. This can introduce significant costs in laboratory analyses or bias in cases where genetic confirmation is not being done prior to analysis. Thus, only experienced dog teams should be considered for use on a study (Long *et al*. 2007).

Another consideration of the method should be the objectives for the study. As jaguars cover extensive areas and have low defecation rates, we cannot expect to get detailed movement information. When physiological, genetic, presence/absence, disease and parasite, or diet information is warranted, however, scat samples will provide the most effective means of gathering this health panel of information. However, for some laboratory analyses, samples have to be reasonably fresh. In general, study design is crucial for effective sampling and professional outfits can provide advice for effective study design.

Conclusion

The choice of any methodology for studying jaguars depends on the purpose of the study, site location and the research team's experience and available resources. While jaguar capture is still the most reliable methodology for biological sample collection and necessary for telemetry studies, due to the risks involved in these procedures researchers

Fig. 5. Male radio-collared jaguar passing a camera trap station in Emas National Park, central Brazil (Photo Jaguar Conservation Fund/Instituto Onça-Pintada).

tend to substitute them for non-invasive methodologies. Information of species-specific capture accidents and fatalities need to be published so that future captures do not repeat past mistakes. Camera traps and especially GPS collars are still relatively young technologies that continue to be improved and adapted to particular field situations, as demonstrated by the TrackTag collars used in the Amazon. Likewise, training of detector dogs is becoming more sophisticated allowing even identification of individuals from scats (Kerley & Salkina 2007). Until the last decade, the jaguar was the second least studied large cat in the world. With improving technology and analytical methods, the upwards trend in jaguar research stands a good chance to continue.

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Fig. 6. Author Carly Vynne with scat detector dog surveying for jaguar scats in the surroundings of Emas National Park, central Brazil (Photo M. Baker).

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