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A minimally invasive capture system for the safe and compassionate live-trapping of jaguar and puma

Un sistema mínimamente invasivo para la captura segura de jaguares y pumas

Francisco Palomares*

Estación Biológica de Doñana, CSIC, Departamento de Biología de la Conservación, Avda. Américo Vespucio 26, 41092 Sevilla, Spain

* ffpaloma@ebd.csic.es

Abstract

Live trapping of large carnivores can have counter-productive effects on the animal's health and post-release behavior. Nonetheless, trapping may be necessary for scientific inquiry, wildlife management and conservation. Capture methods should be efficient, selective, compassionate, and safe for both animals and people. Here, I review the methods used to capture the largest American felids, jaguars and pumas, and propose the use of a minimally invasive capture system (MICS). The device consists of a blowgun remotely controlled by means of cameras and a swiveling 2-way pan-tilt head. The blowgun is monitored by video camera and triggered from a distance of up to 400 m and is capable of shooting darts with high accuracy at distances of about 12 m. This method was developed a decade ago but has not been used despite clear advantages over traditional methods. The use of a MICS can be cheaper, lower in human investment, higher in efficiency and selectivity, and safer and more compassionate than the traditional methods used. The main disadvantages are related to manufacturing, as it must be custom built made by a specialized professional. In addition, any adjustments or repairs must also be handled by a specialist. Nevertheless, these challenges should not discourage the use of MICS, as ethical considerations are of growing importance worldwide when working with wild species. The use of MICS for the live-capture of wild jaguars and pumas (or other medium and large carnivores) deserves further consideration, testing, and discussion.

Keywords: *Panthera onca, Puma concolor*, safe capture, trapping methods.

Resumen

La captura de grandes carnívoros vivos puede tener efectos contraproducentes sobre la salud del animal y su comportamiento posterior cuando se libera. No obstante, la captura puede ser necesaria para la investigación científica, la gestión o la conservación de las especies involucradas. Los métodos de captura deben ser eficientes, selectivos, compasivos y seguros tanto para los animales como para las personas. En este artículo se revisan los métodos utilizados para capturar jaguares y pumas, y se propone el uso de un sistema de captura mínimamente invasivo (MICS). El dispositivo consiste en una cerbatana controlada a distancia por medio de cámaras, y es capaz de disparar dardos con alta precisión a distancias de hasta 12 m. Este método se desarrolló hace una década, pero no se ha utilizado a pesar de las claras ventajas con respecto a los métodos tradicionales. El uso de MICS puede ser más económico, necesitar de menor inversión humana, tener mayor eficiencia y selectividad, y ser más seguro y compasivo que los métodos tradicionales. Las principales desventajas están relacionadas con la fabricación, ya que debe ser hecha por un profesional especializado, y cualquier ajuste o reparación debe ser realizada por un especialista. Sin embargo, estos desafíos no deben desalentar el uso de MISC, ya que las consideraciones éticas tienen una importancia creciente a nivel mundial cuando se trabaja con especies silvestres. El uso de MICS para la captura en vivo de jaguares y pumas (u otros carnívoros medianos y grandes) merece mayor consideración, prueba y discusión.

Palabras clave: Captura segura, métodos captura, *Panthera onca, Puma concolor*.

Introduction

Live-trapping of large wild carnivores involves several challenges, mainly related to: 1) the capturing system used, which may cause unintended and indirect harm to animals such as injuries, stress and the disturbance of ecological processes, such as reproduction or territory maintenance; 2) the safety of researchers and handlers during capture; and 3) trapping effectiveness and logistics, considering affordability and efficiency (Shury 2007, Fraser & MacRae 2011, Ramp & Bekoff 2015, http://compassionateconservation.net/). The ideal trapping system should be efficient, selective, compassionate, and safe for both animals and people.

Here, I discuss the feasibility of using a new trapping method, a minimally invasive capture system (MICS; Ryser *et al.* 2005), for the live-trapping of the two larger felids of the Americas, the jaguar *Panthera onca* (Linnaeus, 1758) and the puma *Puma concolor* (Linnaeus, 1771). Secondly, I propose a possible protocol for its use. The MICS has been developed and tested with a medium-sized felid, the European lynx *Lynx lynx* (Linnaeus, 1758), and has potential as an adequate capture method for the large felids. However, until now, no studies have been conducted to test this method for the capture of wild jaguars, pumas or any other large mammal species, despite the a priori advantages over other, more conventional methods (see next section and Ryser *et al.* 2005). This method has been shown to be efficient, selective, and may be safe for animals and people (Ryser *et al.* 2005).

The MICS in this study consists of a tele-guided blowgun, remotely controlled by means of a camera and a swiveling 2-way pan-tilt head (Fig. 1), which is installed at sites where animals are known to return such as baiting or feeding sites, kill sites, dens, or water holes (Fig. 2). The entire device may be fixed on either a tripod or a trunk platform (Fig. 2). The MICS is commanded from a control panel by either a cable or a wireless connection by

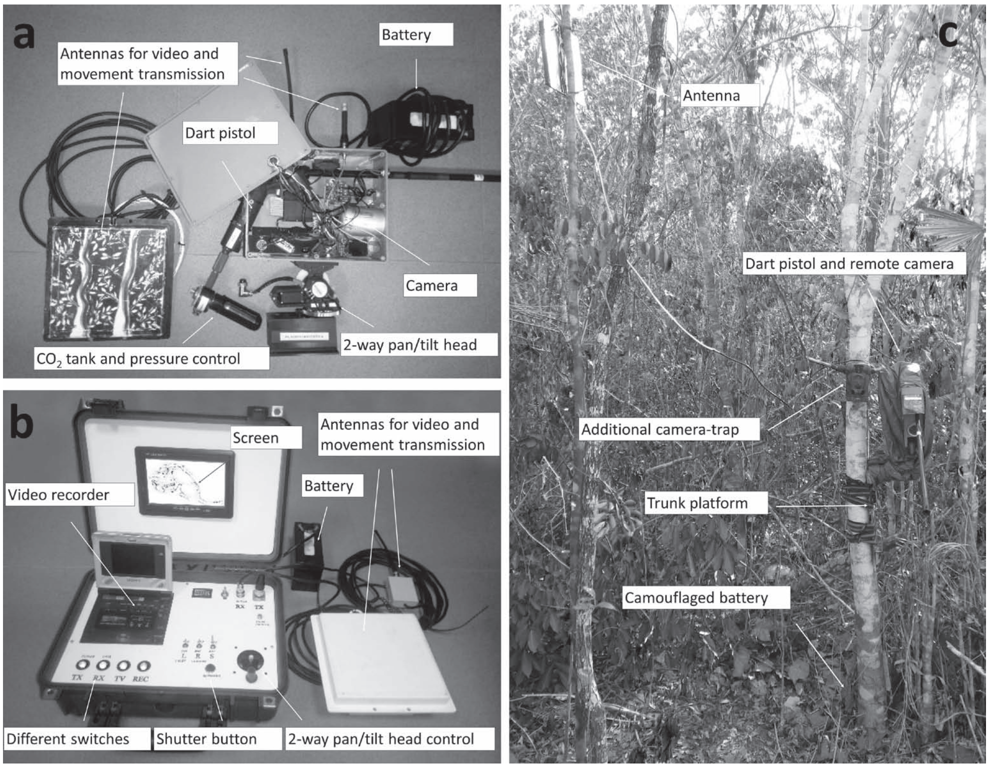

Figure 1. Main components of the MICS. a) Box with the dart pistol and the video camera attached to the 2-way pan-tilt head for remote control; antennas for wireless video and radio signals; and the battery to charge the system. b) Briefcase with the 2-way pan-tilt control, shutter button, screen to see the image from the box camera, a video recorder, and different switches to connect and disconnect the remote MICS box and batteries; antennas for wireless video and radio signals; and the battery to charge the system. c) Box with the dart pistol installed in the field; an additional camera trap is also set at the site previous to the MICS installation to check for species, sex and size of animals visiting the site. A complete description of the electronic components of the MICS in Ryser *et al.* (2015).

a radio signal between two antennas up to 500 m apart (Fig. 1 and 2). The control panel allows an operator to view the area where the tele-guided blowgun is installed, to move the pan-tilt head with the MICS on 2 axes, and to trigger the dart (Fig. 1). The device also allows digital video recording of the entire capture, allowing an analysis of the animal's reaction during the test phase (Fig. 1). The blowgun is capable of shooting darts with average accuracies of 6 and 14 mm at distances of 6 and 12 m, respectively, and the darts are fitted with a radio-transmitter to locate them if the darted animals move from the site (Ryser *et al.* 2005). Detailed information on the capture devices can be found in Ryser *et al.* (2005).

Comparison of live-trapping methods for jaguars and pumas

Jaguars and pumas are usually captured with box or cage traps (Rabinowitz 1986, Azevedo & Murray 2007, Allen *et al.* 2014), trained hounds (Rabinowitz 1986, Schaller & Crawshaw 1980, Crawshaw & Quigley 1991, Silveira 2004, Soisalo & Cavalcanti 2006, McBride Jr. & Mc-Bride 2007, Azevedo & Murray 2007), leg-hold snares (Logan *et al.* 1999, Goodrich *et al.* 2001, Araujo 2015), or rubber-padded foot-hold traps (Hoogesteijn *et al.* 1996). These methods, however, are not exempt of risk to the animals or to the personnel involved in the captures. They are not fully selective and their efficiency is generally limited, requiring great time and effort (see below). Table 1 presents an evaluation of all capture methods used for the live-capture of jaguars and pumas in relation to these considerations, as compared to the potential use of MICS. For the evaluation, I used an approach similar to Shury (2007), which considered the following issues: cost, capture efficiency, portability, potential for injury to animals and selectivity. To this issues, I added others such as human investment, capture efficiency, operational constraints, stress for animals, predation, discovery by humans and risk of injury to people. Description of each issue is in Table 1. Below, I briefly comment on each of these topics (also e.g. see Logan *et al.* 1999, Furtado *et al.* 2008, MacCarthy *et al.* 2013, Araujo 2015 among others). The evaluation attempts to provide a general overview of the subject. Thus, I recognize that for

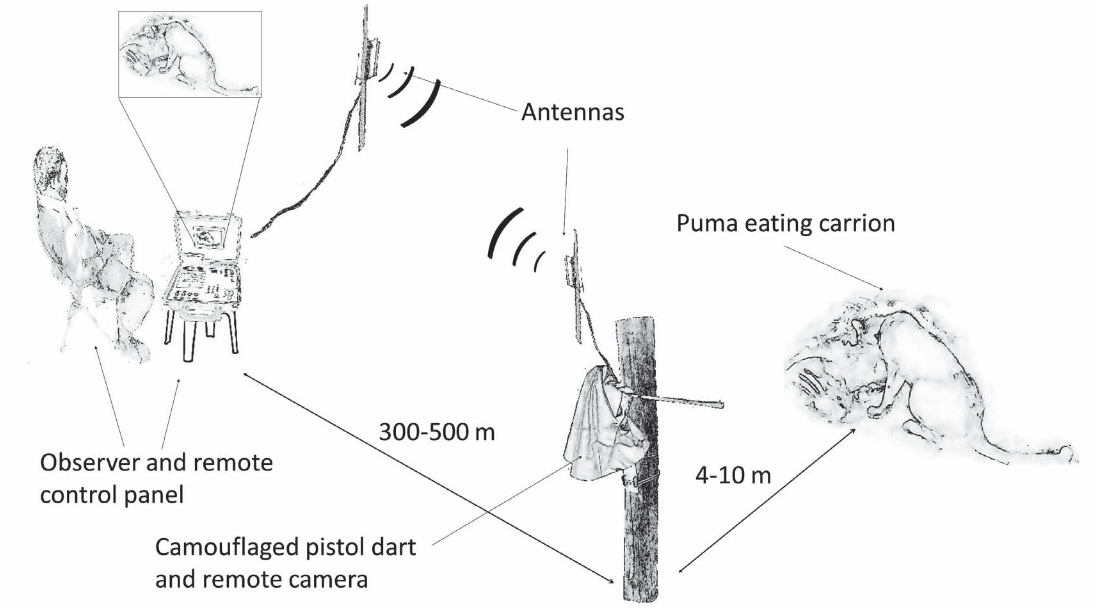

Figure 2. Sketch of the MICS installation in the field. MICS box may be installed in a trunk at a distance between 4-10 m from the place where a bait is set for pumas or jaguars. The observer may be waiting at a distance, between 300-500 m, and he/she can watch the screen's briefcase and can move the box and shutter the dart through the briefcase buttons (see Fig. 1). Antennas can be set close to the box and briefcase, or as far from them as needed using an extension cable if transmission is poor due to rough terrain or too much vegetation. Additionally, the observer may wait in a vehicle and connect the MICS briefcase to the vehicle battery.

Table 1. Comparisons of several considerations for the live-capture techniques of jaguars and pumas. Modified criteria based on Shury (2007), which we added human investment, capture efficiency, operational constraints, stress for animals, predation, discovery by humans and risk of injury to people. Bold italics indicate the best-ranked technique for each consideration.

	Capture methods				
	Box-traps	Leg-snare traps	Foot-hold traps	Trained hounds	MICS
Cost of devices[a]	Moderate to High	***Moderate***	***Moderate***	High	***Moderate***
Human investment[b]	Moderate to High	High	High	***Moderate***	***Moderate***
Portability[d]	Low	Moderate to High	Moderate to High	Moderate	***High***
Capture efficiency[c]	Low	Low to moderate	Low to moderate	Moderate to High	***High***
Potential for injury to animals[e]	***Low***	Moderate to High	Moderate to High	Moderate to High	***Low***
Selectivity[f]	Low	Low	Low	Moderate to High	***High***
Operational constraints[g]	***Low***	Moderate	Moderate	High	High
Stress for animals[h]	Moderate	Moderate to high	Moderate to high	High	***Low***
Predation[i]	***Low***	Moderate to high	Moderate to high	***Low***	***Low***
Discovery by humans[j]	Moderate to high	Low to moderate	Low to moderate	***Low***	***Low***
Risk of injury to people[k]	***Low***	Moderate	Moderate	High	Moderate

[a] For this issue Shury (2007) considered the cost per animal captured on a relative basis, and here we considered the economic cost of devices.

[b] Number of people and operational time needed for trapping and handling of animals.

[c] Number of animals that can be quickly captured in a short period of time.

[d] Ease of changing to different capture locations quickly and efficiently; this does not include transportation to the study area.

[e] Potential for injury to the captured animal.

[f] Ability to avoid capture of non-target species or individuals.

[g] Possibility of failed captures or malfunction.

[h] Stress on animals due to the capture process.

[i] Potential for predation of the captured animals.

[j] Potential for the captured animal to be discovered by poachers or other people.

[k] Potential for injury to people when approaching or handling captured animals.

particular study areas or situations, this evaluation may not be adequate. In selecting a capture method, researchers must take into consideration legal regulations and requirements in the country (or state) of study, climate, vegetation, topography, logistics, time considerations, project staff numbers and expertise, budget, and the density and behavior of the target species in the study area. Clearly, capture efficiency and the potential for injury to animals or humans will depend on the experience and ability of the personnel involved. When using trained hounds, the cost and feasibility will depend on whether the project has its own dogs and/or the distance they must be transported. Similarly, the use of snares or foot-holds will be difficult in areas without an adequate system of roads and trails.

Equipment investment

Taking only the cost of the capture devices into consideration, snares are the cheapest, followed by foot-holds, box traps and trained hounds. The total value of the materials in a MICS system costs around $4,000 (US), including the dart pistol, which is also needed in all other capture methods. Thus, it may be more expensive than one unit of the other devices. However, one or two MICS systems may be sufficient for an entire project (see the proposed protocol for jaguars and pumas below). With other methods, several capture devices or dogs are needed, and therefore differences in cost are minimal, or are even higher in the case of dogs.

Human investment

To avoid or minimize injuries to animals, snares, foot-holds and box-traps should be checked every 1-2 hours (directly or by radio-telemetry; Logan *et al.* 1999, Goodrich *et al.* 2001, Cattet *et al.* 2003, Araujo 2015). Additionally, snares and foot-holds should be set up every day in the afternoon and set off again in the following morning. Thus, the research team (at least 3 people) must work at least 2/3 of the day and be ready to act throughout the trapping period. The use of trained hounds requires more people, but is more concentrated on a few given days and shorter time periods (Furtado *et al.* 2008).

The MICS would only be installed when it is known that there is a high probability animals are going to return to a given point (for instance for feeding; see section *Attracting animals to a given point for darting*). In these circumstances, previous data for MICS with European lynx indicated that wait times before captures were 2 hours on average (Ryser *et al.* 2005), and similar times may be expected for pumas and jaguars after they begin activity as they typically rest in close proximity to kills or carcasses where they were feeding the previous day. Allen *et al.* (2015) found that pumas stayed within 150 m from kills, while Anderson & Lindzey (2003) found an average distance of 844 m. In a few experiences with pumas in Sao Paulo (Brazil) and jaguars in Mexico, animals returned to kill sites earlier than 3 hours after sunset (author, unpub.). On the other hand, at least three people are needed for captures, but only one person is needed to check whether any animals are in the area where the device would be installed (see below).

Portability

Snares and foot-holds are easily transported compared to box-traps, and when using a vehicle, it is possible to take several capture devices at a time. Box-traps always need the support of a pickup truck, so they cannot be used in areas without roads or on rugged terrain. Trained hounds also need one or two pickup trucks to move around the study area until a fresh signal of felids is found. On the other hand, the amount of time for installation (not including the tracking of the area to decide where to set up the traps) is <1 hr for box-traps and longer for foot-holds and snares, as the terrain and the path normally require preparation prior to setting up the traps.

The MICS system described in Ryser *et al.* (2005) weighs 38 kg, and can therefore be carried by two people to a location far away from roads if needed. Approximately 1 hour is needed to set up the MICS.

Capture efficiency

There are few detailed studies on the capture efficiency of these different methods, but available data indicate that boxes, foot-holds and snares are of low efficiency. On the other hand, in the Pantanal (Brazil) and in Mexico, between 2-3 months and 4 months were needed to capture 11 and 4 jaguars, respectively, using trained hounds (Azevedo & Murray 2007, Palomares *et al.* 2009, and F. Azevedo, pers. com,). Nevertheless, in areas where it may be easy to locate recent tracks and with a relatively high density of animals, the use of trained hounds could be more effective, even achieving one jaguar capture per week (Furtado *et al.* 2008, P. Crawshaw, pers. com.). Sometimes between 100 and 300 snares/day are needed to capture one puma or jaguar (Logan *et al.* 1999, Sweanor *et al.* 2000, Araujo 2015), and frequently animals become trap-shy due to their own previous captures or those of close relatives (Logan *et al.* 1999, S. Ferreira, pers. com.). Thus, although this has not been quantified, it is typical that many animals will move near trapping devices without being captured. The capture efficiency of snares (or other capture techniques) considerably increases when set around carcasses and baits where animals are known to be feeding (e.g. 10-25 snare days/capture, Logan *et al.* 1999, Bauer *et al.* 2005, F. Azevedo pers. com., P. Crawshaw, pers. com.).

Previous experiences using MICS with European lynx showed a high efficiency of the method once animals are known to be feeding on a carcass. On 11 occasions in which a lynx approached the MICS, 7 were captured (i.e., 1.6 MICS installations/capture), and some of the non-captures were due to a problem with the initial design of the MICS, which was subsequently solved (see Ryser *et al.* 2005 for details). There is no quantification of MICS efficiency over a long time period that includes the time needed to attract animals to a point or the time needed to detect a carcass at which to install the MICS, but this may be one of the most critical issues when using the MICS.

Injuries and stress

Box or cage traps may produce abrasions on the face of animals or damage to teeth when animals try to escape. This behavior is accentuated when people approach the trap (Rabinowitz 1987, Deem 2004, Furtado *et al.* 2008). Foot-hold and snare devices may produce several types of wounds to animals, or cause death. Logan *et al.* (1999) describe the injures in pumas captured with snares from swelling, to skin damage, bone fractures, and death in 1.9% of captures. The personnel setting up the traps must be very experienced to prevent or minimize injuries when animals try to escape from capture devices (Araujo 2015). Finally, between 0 and 8% of deaths were recorded when using trained hounds to capture pumas and jaguars due to dog attacks or the animal falling out of a tree after anesthesia (Hornocker 1970, Ross & Jalkotzy 1992, Furtado *et al.* 2008, Elbroch *et al.* 2013, and Lindzey *et al.* 1989 and Anderson *et al.* 1992, cited in Logan *et al.* 1999). Furthermore, all of these capture methods may produce stress in the animals with immediate subsequent consequences (Cattet *et al.* 2003). MacCarthy *et al.* (2013) recognized and discussed three critical components leading to stress in captured animals: 1) the amount of time spent in the trap after capture; 2) the proximity of humans before immobilization; and 3) the animal's capture history. When trained hounds are being used for captures, it is important to consider the stress produced on animals during the approach and interaction with the dogs (Harlow *et al.* 1992).

The main risk of injuries in using a MICS is related to the darting, which is also true in other capture methods (Deem 2004). With the proper training and the responsible behavior of the operator, the potential for injury is very low. Tests undertaken with the MICS showed that the precision of shooting from between 6-12 m was on average 14.2 mm (±11.7 mm; Ryser *et al.* 2005), which is very precise for felids of these sizes. Depending on the study area characteristics, it is not advisable to use the MICS in the vicinity of cliffs, fast running waters, or roads with heavy traffic. The lack of any holding device (as also occurs when using dogs) includes potential risks during the induction period of anesthesia, as the animal is free to move after the delivery of the drug. On the other hand, since the animals have not had direct contact with humans prior to sedation, and there is no holding device involved in the process, the method should be nearly stress-free (Ryser *et al.* 2005).

Selectivity of species or individuals

The only current method used that provides some selectivity during the capturing process is the use of trained hounds. Box, snare or foot-hold traps may capture many different non-target species (Logan *et al.* 1999, Riveiro 2015). Dogs may be trained to track only a given species, but dogs must be experienced, obedient and well trained (Furtado *et al.* 2008). Nevertheless, with this method you cannot select a non-tagged individual for capture, which is important to save resources and time, and prevent any subsequent negative consequences for the animals.

The use of a MICS ensures total selectivity of the species and the individual trapped (including pregnant females or females with cubs), as the trapper always sees animals, and can therefore decide whether or not to shoot.

Operational constraints

Box traps are easily set up in the field. Setting snares and foot-hold traps requires more training, similar to when using dogs, which must involve experienced personnel. If any mechanism of the box, snare or foot-hold traps fails, it can be easily solved. Once animals are restrained, anesthesia is easily administered when inside a box-trap. This is more complicated when animals are in snares or foot-holds, and a dart projector must be used to deliver anesthesia from a distance. When using dogs, the logistics of the operation are greater and darting is often done from greater distances either from the ground or by climbing a nearby tree. Furthermore, a capture net must be readied to avoid injury if the animal falls from the tree. If the animal is anesthetized in the tree, a team member must climb the tree to tie a rope around the animal and lower it to the ground (Furtado *et al.* 2008, pers. obs.). All methods can fail to trap animals due to a mechanical malfunction, or in the case of dogs, when felids enter, for instance, a cave. However, there is no formal quantification of this. For animal welfare reasons (Logan *et al.* 1999, Goodrich *et al.* 2001, Cattet *et al.* 2003), no more than the capture of one individual per day is advisable, so snares or foot-holds must be concentrated in small areas either to diminish the probability of capturing several individuals, or such that trappers can quickly close the other devices once one animal is captured.

Any malfunction of the MICS device requires specialized personnel to repair, so it can be difficult to address this in the field. Normally, there is only one opportunity for capture (but see Bauer *et al.* 2005, Ryser *et al.* 2005 for reported cases of captured or disturbed animals coming back to the bait, which may provide additional opportunities of capture in the same session). To prevent partial drug injection, collared needles, which ensure total drug injection, are recommended. Unfortunately, if the felid is not adequately immobilized and cannot be restrained, the dart will remain in the animal and may cause a local infection (Deem 2004). Another important operational constraint of the MICS is that the target animal must appear at a previously defined location (e.g., baiting or feeding sites, kill sites, dens, or water holes), so these places must be initially detected or artificially created. For instance, the implementation of sporadic or permanent feeding sites to attract animals to specific points could be assessed to assist with this phase of the process (Bauer *et al.* 2005, Lopéz-Bao *et al.* 2008, and see section *Attracting animals to a given point for darting*).

Predation and discovery by humans

Animals may be discovered by other predators or even people, which could kill them while in the traps, even in protected areas (Carvalho & Morato 2013). The only method where this possibility is not likely is when using trained hounds. With other methods, the risk is higher the longer the animals are in the capture devices. Thus, minimizing the time the animal spends in the trap is advisable, requiring frequent monitoring of the device, with a consequent increase in effort as mentioned above.

Using a MICS, the risk of predation by other animals or discovery by humans is very low (if any) since, under normal circumstances, the research team will reach the position of the sedated animal within only 10-15 min.

Human safety

The box-trap is the safest capture method for those handling the captured animal. Snares and foot-holds can impose a risk when handlers approach a captured animal, particularly if they stand too close to the trap when trying to dart the animal, or when the animal escapes from the device in an attempt to avoid close proximity with the person. Perhaps the riskiest method in terms of human safety is the trained hound, as the handler must quickly follow the dogs, often in forested and/or rough terrain, possibly exposing them to dangers such as snakes, ankle sprains, falling, felid attacks, etc.

The lack of a holding device when using a MICS may cause risk to researchers in searching for the target jaguar or puma, given the unknown status of the anesthesia, likely at night and/or in dense-cover habitat. This can be particularly important in areas where jaguars and pumas are quite large. Thus, additional safety protocols should be considered if darted animals cannot be observed from a distance or approached in a vehicle: 1) anesthesia should be delivered in full by using collared needles (see section *Efficient installation and use of the MICS*); 2) a transmitter can be inserted into the dart, to be used with a motion sensor to detect the movement of darted animals; and 3) the upper range of recommended doses for the weight and size of the target individuals should be used. Regarding this last recommendation, a researcher will know the species, sex and size of the individual to be captured (see below), and thus it is possible to calculate the quantity of the drug that must be administered. Finally, researchers must wait for animals arriving at the potential capture point, and this implies some additional risk if they are not, for instance, inside of a vehicle.

Proposal of a MICS protocol to capture jaguars and pumas

Ryser *et al.* (2005) provided an excellent description and discussion of the potential use of MICS for capturing medium and large mammals. Here, I focus on its potential use for the live-capture of jaguars and pumas (Fig. 2). Although the capture method must always be adapted to the conditions of each study area, the following four general steps should be considered to efficiently capture jaguars and pumas using a MICS.

1) Deciding where to install the MICS

This is a fundamental step in the use of any capture method for cryptic and low-density species. Trappers must know where the animals are or where they move frequently in order to capture the target species. Thus, it is always preferable to first find these areas rather than randomly placing traps (Dietz 1984). When using a MICS, this is particularly important as the device cannot be randomly installed, while a researcher waits for the animals to come into contact with the device. First, the general area that is used frequently by the animals of interest must be located, and then the specific points at which to set the capture device can be identified. For jaguars and pumas, these points are primarily kill sites, where they can be opportunistically found (e.g., jaguars preying on cattle in the Pantanal or turtles on the beaches of Costa Rica; e.g. Carrillo-Jiménez *et al.* 1994, Azevedo & Murray 2007, Calvacanti 2008), or after tracking in the snow (e.g., pumas in several regions of North America; e.g. Laundré & Hernández 2003). In other cases, researchers should create kills or feeding sites (see below), which can be placed along car-tracks or trails since both jaguars and pumas frequently move along these areas (Harmsen *et al.* 2010, Palomares *et al.* 2012). Relatively open spaces of between 4-10 m should be identified or cleared. A sturdy tree on the edge is useful in the absence of a tripod or other support (Ryser *et al.* 2005; Fig. 1).

2) Attracting animals to a given point for darting

Once an adequate site has been located, the animals must be attracted to the corner (4-10 m distant) opposite to where the MICS is going to be installed (Fig. 2). Carcasses can be used (Bauer *et al.* 2005, Michalski *et al.* 2007) as bait. The use of capture devices with kill caches and carcasses has been more successful than other approaches (see above).

Carcasses are a good option when climate conditions allow and when the meat will maintain a good condition over several days in the field. Both species of interest are attracted by carcasses (Logan *et al.* 1999, Bauer *et al.* 2005, Cavalcanti 2008, Araujo 2015). Bauer *et al.* (2005) found that pumas will eat at 43.5% of carcasses set in fields, and bait sites were visited by 1 to 4 scavenging pumas. To improve attraction and success in the location of the carcasses by felids, sound and visual stimuli of potential prey species can be used. Carcass placement should minimize detection by aerial scavengers, by simulating the natural places that pumas and jaguars use for caching (Bischoff-Mattson & Mattson 2009).

3) Achieving the predictable return of the animals to the point of interest

As previously stated, the ideal scenario is to install the MICS in a location where the probability of the target animals re-visiting the capture point is high. Both pumas and jaguars are known to stay close to kill sites and carcasses and feed over several consecutive days. For pumas, handling times for prey > 15 kg may be 1-15 days (Anderson & Lindzey 2003, Bauer *et al.* 2005, Allen *et al.* 2014);

even in the case of smaller prey, pumas may feed for 1 to 6 days (Anderson & Lindzey 2003). However, if large scavenger species are present in the area, this time could be reduced (Allen *et al.* 2014). Replacing carcasses can increase the number of days that pumas feed (Bauer *et al.* 2005), which may be useful to settle the animals at a specific point until they can be captured. This behavior has been corroborated in other felid species, including the Iberian lynx (*Lynx pardina*), with supplementary feeding experiments (López-Bao *et al.* 2008). Cavalcanti (2008) provided detailed information about the amount of time that jaguars remain in the vicinity of carcasses, with the duration significantly higher in larger prey. She found the average number of hours that jaguars remained in the area of carcasses was 16 for prey < 15 kg, and 28 for prey > 200 kg, but in both cases there were occasions when jaguars stayed for 80 and 100 hours, respectively. Nevertheless, these data are conservative as the time was calculated for consecutive locations < 100 m from the carcasses, and did not consider whether animals returned after moving greater than 100 m. Thus, once a relatively large bait (at least 15-20 kg) is detected by a puma or jaguar, one can expect that the animals will continue feeding on the bait for several days, and even longer if additional bait is provided at the same location.

It is important to note that felids should not be able to drag carcasses to another location, a common behavior in both species (Bischoff-Mattson & Mattson 2009, pers. obs.). Thus, tethering the bait firmly to a tree or stake is a precondition to ensure the felid's return to the same site at which the MICS is installed.

Bait sites should be revisited every day to check for any visits by the target species. Once a visit is recorded, the MICS can be installed. The setting of a camera-trap at the same location (Fig. 1) is needed to help with the identification of species and individuals responsible for feeding. Additionally, this will allow for the determination of the sex and body mass of the individual involved (important for the estimation of drug doses), and to check whether animals are approaching the bait in the expected position (see below).

4) Efficient installation and use of the MICS

Jaguars and pumas usually return to kills or carcasses once discovered soon after sunset (Bauer *et al.* 2005, pers. obs.; see above). Thus, the device should be installed much earlier. The MICS should be between 4–10 m from the bait, distances at which shooting is very accurate (see above). The bait and the MICS should be placed such that the felid presents its body in a lateral position to allow for darting of the caudal thigh muscles (Fig. 2). Previous experience with the European lynx indicates that animals sometimes flee up to 200 m from the bait in reaction to being hit, and at other times they remain close to the baits (Ryser *et al.* 2005). Therefore, the dart syringe must be equipped with transmitters to locate felids by means of radiotelemetry, if needed. As mentioned before, the needles used with the darts should be collared such that they will remain in the animals. This helps to both ensure total drug injection (Deem 2004), and that the target animals are successfully found after flight.

For reasons of efficiency and safety (see above), it is important to ensure that caught animals are in deep sedation when the research team approaches. Experiences with European lynx show that when using MICS, similar doses of drugs produced a higher sedation effect on animals than other capture methods (Ryser *et al.* 2005). Therefore, using the safe upper range of expected doses for a deep sedation should be sufficient to prevent this potential problem. For safety reasons, it is always better to anesthetize the animals before feeding; it is recommended that they be darted soon after arriving to feed on carcasses.

Conclusions

The use of MICS for the live-capture of wild jaguars and pumas (or other medium and large carnivores) deserves further consideration, testing and discussion. A priori, it seems that MICS could present some advantages over other, more traditional methods, including lower cost and human investment, increased efficiency and selectivity, and increased safety and compassion for captured animals. On the contrary, the main disadvantages compared to other methods are related to manufacturing, since this device must be custom made by a specialized professional. In addition, any adjustments or repairs must also be handled by a specialist. Nonetheless, these challenges should not prevent the use of a MICS, as ethical considerations are of growing importance worldwide when working with wild species (Ramp & Bekoff 2015).

This technology could be a step in addressing this concern. By combining the consideration of animal welfare and conservation, and following the principles and actions that underpin Compassionate Conservation (http://compassionateconservation.net/about/principles/), a reduction in harm and in the suffering of individual wild animals will be achieved and will improve conservation outcomes.

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