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WILDLIFE MONITORING AND CONSERVATION: HOW BOOSTING DATA COLLECTION THOUGH THE USE OF CAMERA TRAPS

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Index

ABSTRACT

Monitoring wild animals using camera traps is a crucial conservation tool. Nowadays, the advancement of this technology has significantly increased the volume of data available for analysis. However, due to its complexity, proper training is essential for effective use. Various factors can influence detection probability, including the camera's detection zone, placement, ambient temperature, animal interference, and even vandalism. Despite these challenges, camera traps are emerging as a valuable alternative to traditional methods for estimating population' stability.

Given that most wildlife species lack natural markings, innovative methods have emerged that utilize camera traps without requiring individual identification. One such method is the Random Encounter Method, which estimates species diversity, density and abundance within a given territory. Moreover, during the soft release phase of reintroduction projects, camera traps can play a vital role in assessing the success of the release by evaluating how animals react and adapt to the new environment.

The diversity of species in an area is crucial for understanding the prey-predator balance, resource availability, and overall environmental health, all of which inform the feasibility of introducing a new individual. In my case study at Alturas Wildlife Sanctuary in Costa Rica, I deployed seven camera traps in a designated area. By analysing the collected data, I calculated species diversity using both the Shannon and Simpson indices. This analysis aimed to evaluate whether the territory could support the reintroduction of a female ocelot currently in the Pre-Release area of the rescue centre where I worked.

INTRODUCTION

The reintroduction of animals has become a significant topic of discussion, requiring expertise from specialists and facing the challenge of diminishing available habitats. Therefore, camera traps have emerged as essential tools, not only for wildlife research and monitoring but also during the soft release of animals. These devices are crucial in the context of ongoing biodiversity loss. It is not just about selecting the right model; factors such as proper sitting place, height, and angle relative to the ground are also vital for effective monitoring.

Initially, camera traps were used to assess the presence/absence of elusive species, to monitor capture site or for behavioural assessment in some specific situations like the ingestion of rabies' vaccine in fox population ("Conservation Biology - 2020 - Gilbert - Abundance estimation of unmarked animals based on camera-trap data.pdf," n.d.). Then, these devices have become widely used in capture-recapture method for estimating animal populations, where individual are captured, marked, and then released. However, the physical capture of animals presented some limitations (Trolliet et al., 2014).

Until 2018, camera-trap studies primarily focused on assessing the abundance of marked (individually distinguishable) animals using both natural and artificial markings. As highlighted in Figure 1.1 (Gilbert et al., 2020), many wildlife species lack natural markings, and the capture can be challenging. Consequently, researchers have begun employing innovative methods that do not require the individual identification. One such approach is the Random Encounter Method (REM), which estimate species density based on effective sampling area covered by an array of camera traps (Gilbert et al., 2020).

Estimating the abundance of unmarked animal populations remains a significant challenge and represents a key frontier for camera trapping. As a matter of fact, multiple detection of an unmarked animals at a camera could represent multiple mobile individuals or a single relatively sedentary one.

The increasing use of camera traps has revolutionized biodiversity monitoring especially for those animals that are nocturnal, avoid humans and seek cover (Gilbert et al., 2020). These devices have been truly significant for wildlife management and conservation throughout the world documenting species that now are new to science or occur in areas where they were thought to be locally extinct or not previously known to exist (Gilbert et al., 2020). Traditional indices for estimating animal abundance are often time-consuming and lack precision. In contrast, camera traps offer a valuable alternative, providing more reliable monitoring and estimates. For instance, prior to reintroducing animals, it is essential to assess the reintroduction area for presence of conspecific, as well as the species richness, and evenness. Species richness is defined as the total number of species within an ecological sample, while evenness indicates the degree to which the relative abundances are similar among species (Maurer and McGill,2011). Together, these two key aspects of species abundance distribution are essential for assessing species diversity, which can be quantified using the Shannon index, a widely used method.

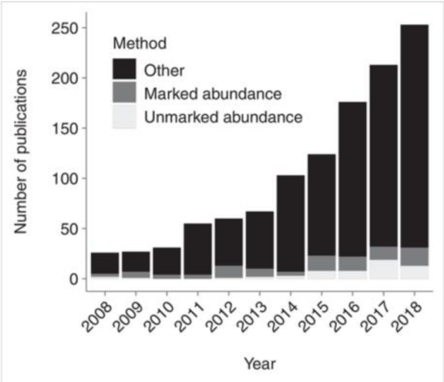

Figure 1.1 *Number of peer-reviewed publications for which researchers used camera traps to estimate abundance of unmarked animals (light grey) and to estimate abundance of marked animals (medium grey) relative to all other applications of camera traps (black) from 2008 to 2018 (Gilbert et al., 2020).*

CHAPTER 1: THE USE OF CAMERA TRAPS

1.1 How camera traps work and the heat challenge

A camera trap's role is to wait in the field the passage of an animal and take pictures or videos of it saving the data. They can give indices of presence of animals, make possible the recognition of animals and how they behave (Apps and McNutt, 2018). Camera traps are excellent tools to look at the distribution of a species, the population dynamic, to identify nest predators, to monitor the reintroduction of an individual or a group and the occurrence of rare and endangered species. From the health point of view, it is very important to monitor how animals' territories, belonging to the same or different species, overlap with each other and whether or not there are direct or indirect interactions between individuals. These interactions are particularly important from an epidemiological point of view for the management and prevention of the spread of diseases.

Camera traps are composed by a camera that is triggered by an animal detector, a flash or floodlight to operate after dark and a SD card; while the most recent devices have the possibilities to transmit remotely the recordings through Bluetooth, wi-fi, GSM etc without the need of a SD card. These cameras are more expensive, and they required more energy to work. The automated camera trap as it is now known came onto the market at the end of the 1980s (Trolliet et al., 2014).

Depending on the model and weather conditions, cameras can be left in the wild for a long period of time. There are many models, but all off-the-shelf camera traps have similar components and basic principle of operation. The effectiveness depends on battery-life, data storage capacity and resolution.

The detection zone is the zone covered by the camera's infrared beam in which the movement can be detected. The zone varies in width and depth (Trolliet et al., 2014), while the field of view is the zone covered by the camera lens, and which appears on the pictures. Nowadays, the most common camera traps have a wide angle of 110-120 degrees, therefore, individuals using some larger area that the camera is assumed to sample may not enter the detection zone (Burton et al., 2015). Indeed, carefully planned sampling protocols can help minimize detection bias, but analytical approaches to contend with imperfect detection are also needed.

There are two categories in which cameras can fit into: active infrared (AIR) and passive infrared (PIR). The active infrared sensor (AIR), only activate and capture an image after an object enters the detection zone, thus breaking the IR beam for a specific period (Brown and Gehrt, 2009). The detection zone is a straight line, which can span up to 150 feet. In addition, it can be set at a desired height to exclude certain species. IR beam is transmitted by the IR (infrared) transmitter, and it is received by an IR (infrared) receiver. A disadvantage of these devices is that the system is activated only when the IR beam is broken, vegetation can be the cause of the activation resulting in recording many images of leaves.

On the other hand, cameras with passive infrared (PIR) sensors represent a majority of remote camera market (Brown and Gehrt, 2009). Figure 1.2. To trigger image capture most of the camera traps use passive infrared (PIR) motion detector that respond when something with a different body temperature with respect to the ground moves in the detection zone. Of course, some camera traps are more sensitive than others but generally clouds that pass across the sun are not enough to trigger the camera because a higher change in temperature is required (Apps and McNutt, 2018). Indeed, the detection zone for PIR system has sensitivity adjustments; the user can set sensitivity high enough to detect even small amounts of change (Brown and Gehrt, 2009). Smaller targets are detected less because they emit less heat, and more distant targets are even more difficult to be targeted because less of the heat they radiate reaches the detector (Apps and McNutt, 2018). Consequently, bigger the animal, higher the heat radiated, so these animals are detected at longer ranges than smaller ones. In addition, there are some species that emit low amount of heat, and this make difficult for the camera to detect them. For this reason, it is possible to set camera traps in a way that they can activate at specific hours of the day or at regular intervals to collect the recordings. Detection range is also reduced when there is not such difference between target's temperature and background. When the camera itself gets hot enough because of the direct light of the sun, the PIR sensor is blinded, and it will not trigger at all until it has cooled down. PIR can take few hours, but it will miss images until well after dusk. That is why it is important to position camera traps in the shade; hot temperatures are one of the major problems when dealing with camera traps because the number of still images captures, or the video are reduced; this is even worse when you want to estimate the animal density.

The manpower to install/remove the camera traps from the field is necessary (Abolaffio et al., 2019), but, nowadays, there are programs that automate the detection of animals like Agouti using the artificial intelligence like *Ecoassist* or *AnimalFinder* (Tack et al., 2016).

The passive infrared (PIR) camera uses a technology known as motion detection: the device is in a state of stand-by until the passive infrared motion detector notices a presence. Most of camera trap detectors have five to seven lenses. Each lens element covers a different zone of the detector's field of view, and the infrared from adjacent zones is focussed onto different elements of the PIR sensor as the target moves across the detector's field of view its infrared image moves from one element to the other with corresponding rises and falls in the temperatures and voltages of the PIR sensor elements. The rate of change of the voltage sends an electrical signal that is used to trigger the camera (Apps and McNutt, 2018). Figure 1.3 Lenses have a vertical arrangement, so the detector is more sensitive to animals that move tangentially across its field of view because it generate the sharpest changes in infrared sensor temperature and voltage, Figure 1.4 (Apps and McNutt, 2018).The detection is lower in the edge of the field of view because, although an animal is moving into a detector zone, it is not moving out of one, and maximum sensitivity depends on the signals from PIR elements rising and falling simultaneously as the target moves into one detection zone and out of another. In few words, the detector will sense the animal when it moves from one zone to another and then it will send a signal to the camera to take the picture (Apps and McNutt, 2018). What the camera detects is the animal's surface temperature and not the body temperature. The core temperature is not necessary its surface temperature especially for animals that are wet or covered in fur or feathers.

The time between when the animal enters in the image field of view and when the image is captured is the trigger delay (Apps and McNutt, 2018). The trigger time is very rapid, generally around 0.1-0.3 sec. Especially when the animal is closed to the camera, there could be that the animal has left the field of view when the image is taken. Between one photo and the next, it is necessary a recovery time before capturing another one (Apps and McNutt, 2018). This limits somehow the number of images that can be captured. Recovery times are usually longer than trigger times, 0.5–3.4 s for still images and 0.7–5 s for videos (Apps and McNutt, 2018). It is possible to set the camera to shot multiple images after the first trigger without the need for the PIR detector to trigger again; this is what is called burst shooting (Apps and McNutt, 2018).

Nighttime pictures are very useful especially for nocturnal animals. There are two methods that can be used to take night photography: the use of incandescent flash or infrared light. The first one allows colour pictures, which generally are of better resolution. The amount of light captured is higher and this is critical for individual animal identification with the use of tags or natural marks. However, flash can seriously scare the animal (Apps and McNutt, 2018). The second method uses infrared light and it is more discrete; consequently, it is very popular even if it produces black and white images (Trolliet et al., 2014). Infrared image quality is very variable and depends on the models (Apps and McNutt, 2018). However, the best solution to avoid scaring animals is the use of camera with a "no-glow" infrared flash like Bushnel Trophy Cam Black, Covert Black 60 etc. These cameras shot black and white images using LEDs that emit no visible light at all (Trolliet et al., 2014). The resolution is expressed in Megapixels (Mpx) that indicate by how many pixels the image is composed. If your camera trap allows a choice of image resolution, set it equal or slightly higher than the pixel count of the image sensor (Apps and McNutt, 2018). Of course, imagines with a better resolution will consume more rapidly the SD card; it is a sort of compromise.

Generally, the power source of camera traps are batteries; however, in the recent years, cameras power directly by sun light are found in the market. In any case, it is possible to select specific timetable, for example during night for nocturnal animals, to save battery. The choice the camera must consider the level of energy consumption for day and nighttime picture processing (Trolliet et al., 2014).

In any case, probability of detection can be affected by many factors, including a camera's detection zone, as said before, sensitivity and specific placement; habitat characteristics for example, leaves movement that activate the camera) or attractants at a camera; animal temperatures; timing and duration of sampling; animal density and behaviour in the landscape (Burton et al., 2015).

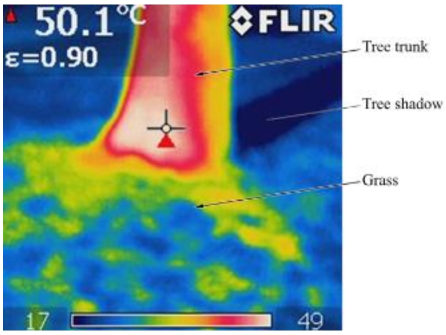

Figure 1.2 *Thermogram of the base of a tree and surrounding grass. Moving objects that are warmer or cooler than background substrates, will cause the camera to be triggered. (Welbourne et al., 2016)*

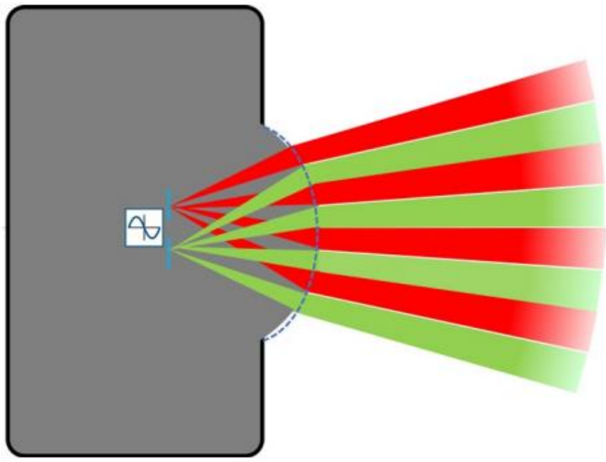

Figure 1.3 *The heat images of alternating, adjacent zones of the passive infrared detector's field of view (red and green) are focussed onto different sensors of the pyroelectric chip (blue lines) by a curved Fresnel lens (dashed blue line) in the front of the camera (Apps and McNutt, 2018).*

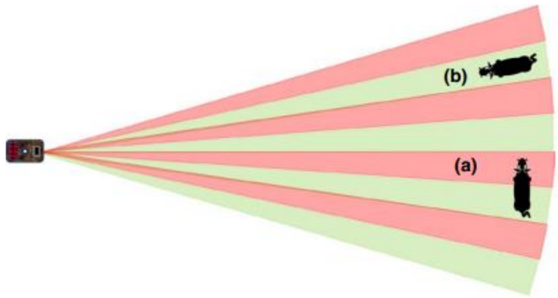

Figure 1.4 A typical passive infrared detector zone layout of a camera trap; animal A is detected as it crosses from one zone to the next, but animal B can move almost to the camera without leaving a zone and so will not be detected (Apps and McNutt, 2018)

1.2 Camera siting, mounting and aiming

When deciding where placing the camera, it is important to choose sites that consider the habits of the study animal, the paths, water sources, wallows, scent-marking, carcasses sites etc. This will increase the quantity and quality of the camera trap data (Apps and McNutt, 2018). Consider the differences among species to decide the angle, the height in the tree etc that are highly dependent on the animal. Mount and aim cameras to quickly detect the animals after they walk through the field of view. This is the general rule but in case in which the Random Encounter Method is applied, camera placement is determined a priori by precise geographical coordinates that follow a gridded design (Cusack et al., 2015a).

Cameras are very sensitive to the height and angle: few cm can make the difference. If the surface in front of the camera is completely flat, the detection zone will be completely straight in front, but for some animals it is better to tilt the camera in a way that allow a better perspective.

To be sure to catch the animal, maintaining sensitivity and detection range, mount the camera just below the target animal's shoulder height (Apps and McNutt, 2018). Pay attention during rainy season because the lens window can get splashed with dirt by heavy rainfall if are position below about 30 cm (Apps and McNutt, 2018).

Cameras can be fixed to tree trunks, holes, rocks etc; in case the device is poisoned around a tree, it is not tight immediately to find the right position, for example above vegetation to obtain a clear view. It is possible to position some branches to create the angle that take the perspective of the animal of interest before fixing it using tape. Important that the tape is not visible from the camera. It could be convenient to clean a little the field of view from vegetation to reduce false trigger; in any case, not remove too much because it would affect the subject's behaviour. In addition, clean the detector and lens window frequently and check every time you visit that the camera has not shifted, especially if accurate aiming is important (Apps and McNutt, 2018). The slope must be taken into consideration: when camera traps are aimed horizontally, the size of the dead zone between the camera trap and the bottom of the field of view increases with height. If a higher camera is dipped forward to bring the nearest edge of the field of view back towards the camera, the maximum range is reduced (Apps and McNutt, 2018).

Siting and aiming camera can be particularly challenging to maximise the quantity and quality of image. To be more sensitive, the camera needs to be close to where animal passes, but it also has to be far enough away for them not to move right across the field of view during the trigger delay (Apps and McNutt, 2018).

Abundance estimate requires reference to space to be meaningful, either by reporting the area to which an abundance estimate corresponds or by estimating population density ("Conservation Biology - 2020 - Gilbert - Abundance estimation of unmarked animals based on camera-trap data.pdf," n.d.). Animal movement obfuscates a clear definition of the sampling area and, as a result, the area to which an abundance estimate corresponds (Gilbert et al., 2020). Several methods address the challenge of space in one of three ways. First, some methods have not any reference to space, so the estimation is assigned to an arbitrary area. Second, some methods estimate abundance within an area explicitly defined in the model by accounting for where and when animals are detected. Third, some other methods estimate density within the collective viewsheds of cameras, which are assumed to be representative of the sampling frame. Depending on the method, the viewshed is defined as either the area within which animals can be detected by the detection zone of the camera or the total area photographed by a camera, the total viewshed (Gilbert et al., 2020).

1.3 Animal interference

It is well known that camera traps can interfere with the natural behaviour of the animal. For the light they emit, their position, the adjustment all around like cleaning some vegetation in front of the camera to allow a better viewpoint etc. If animals could see the light from the camera, it is quite species specific. For example, 940nm IR is invisible to humans but African wildcat and elephants behave as they can see the light. It is crucial to understand it trying to reduce as much as possible this interference (Trolliet et al., 2014).

In addition, pay attention because there are many animals that can cause problems to the camera like elephants, African dogs, hyenas, primates etc (Apps and McNutt, 2018).

1.4 Calibration process

Finding a suitable attachment point to position camera traps is quite challenging, especially in the field. When a suitable placed has been found, calibration process is the following step. To do it, take a straight, strong pole around one meter in length and mark it with visible bands. A correct calibration pole has bands every twenty cm from one end. This is done to highlight the height increment, so that one band is equal to 0.2 m, the second band is equal to 0.4 m etc (Rowcliffe, 2022).

Once the pole has been calibrated, it should be position in front of the camera, starting around 1m away. It is important to hold the pole perpendicular to the ground surface. Repeat this for further pole placements across the field of view increasing the distance from the camera arriving to the maximum extent (Rowcliffe, 2022). The calibration process should cover all the detection zone.

If the camera position is moved or changed, the calibration process should be repeated. The goal of this process is to take picture of animals of known size at a range of known distance from the camera (Rowcliffe, 2022).

Measuring the data collected can be quite challenging; however, calibrated field enables the accurate assessment of the sizes of different species that appear within the detection zone.

Figure 1.3 *Calibration pole, from: Field protocol for camera trap surveys with camera calibration for measuring animal positions for unmarked density estimation (Rowcliffe, 2022).*

1.5 Vandalism

Unfortunately, thefts of camera traps are quite common. This is a serious problem because it implies not just the loss of all the data collected, but also financial consequences (Meek et al., 2016). A study was conducted to see if installing camera traps above humans' eye line, the interference and detection by vandals was reduced. However, it was shown the importance of placing camera traps at a height commensurate with the height of the animal being studied. With cameras placed at higher height the detection rate was reduced, but the resulting data was significantly compromised (Meek et al., 2016). Moreover, higher placed camera traps in trees are more prone to false triggers from tree movement, causing excessive battery usage and reduced card storage capacity (Meek et al., 2016).

Camera traps, even if they vary in model, share camouflaging and security feature designed properly to mitigate detection and theft (Meek et al., 2016). In any case, new strategies and methos should be applied to address this problem.

1.6 Privacy laws

Forests and ecosystems are being controlled using camera traps. It is common for cameras set in remote areas to unintentionally film individuals engaged in a variety of activities, ranging from innocent wanderings through to more nefarious activities such as drug cultivation or poaching. In such case, researchers may have to cope with ethical dilemmas regarding the use of such images to assist law authorities. Indeed, on one side, images may constitute important proofs for investigation and prosecution but, on the other side, the privacy of individuals cannot be excluded for consideration (Franchini et al., 2022). Typically, camera traps are currently unable to distinguish between humans and wild animals, even though new technological innovations are on their way.

The German state of Hessen has banned the use of camera traps that had been set in the forest to detect lynx on the grounds that the Hessen Forest was a public place. Now these devices will be allowed just under specific research projects and in certain parts of the national park where the entry is denied to walkers.

In Australia there are some policies governing how camera trapping for wildlife research should be undertaken. For example, Parks Victoria has developed its Policy on the Use of Surveillance Cameras for Wildlife and Compliance Monitoring, which outlines some general practices to minimise the detection of humans during the wildlife survey. Some organizations in Australia stipulate that signs must be placed in areas where camera traps are being deployed, while others regard it as sufficient to position the signs not necessarily close to the device. This warns people of camera traps deployment, but not the exact location. As a matter of fact, signalling the presence of camera traps the number of devices stolen could increase. This wilful act of petty crime can compromise long- and short-term scientific investigation; moreover, images captured can potentially be accessed by more than those involved in the project posing potential poaching risks.

Talking with the keeper of the rescue centre where I worked, he mentioned that the primary rule me that the only rule regarding camera traps is to obtain the landowner's permission before setting them up. Generally, permits from relevant authorities, such as the Ministry of the Environment and Energy, are required before positioning of camera traps in protected areas.

In Italy, it is mandatory to inform the public about the presence of camera traps in public areas. However, this requirement does not extend to private properties. Additionally, in protected natural parks, it is necessary to obtain authorization from the managing authority before installing camera traps.

Invasion of privacy is a wide international topic that deserves proper attention because it is managed differently among the countries all over the world and a rule valid for all does not exists. (Fleming et al., 2014). This underscores the importance of understanding the relevant laws in the country being studied.

CHAPTER 2: APPLICATION OF CAMERA TRAPS FOR REINTRODUCTION

2.1 Camera traps used for monitoring animals in soft release

When comparing various methodologies for assessing population diversity and abundance, camera trapping emerges as the most effective method for accessing different areas, surpassing line transect and animal track survey.

When reintroducing animals in their natural habitat or in areas considered appropriate for the species because rich in resources and space, camera traps are an essential tool. Not just because photographs and videos taken can give an idea of the abundance of animals in the area, the species richness and evenness, but also because using camera traps it is possible to monitor the animal soon after the release. This is particularly true for the soft release in which monitoring how the animal reacts to the new environment is the aim of the study. However, the use of camera traps is efficient if the released animal stays around without moving away or if a fair amount of camera traps have been placed to cover a wide area.

Animal conservation translocation programmes have become an important tool for conservationists working to recover lost biodiversity (Resende et al., 2021). These programs aim to achieve various conservation goals, including reintroducing species to areas from which they have disappeared, introducing them to new areas outside their indigenous range to prevent extinction, or bolstering current population. Two common release protocols utilized for the translocation of animals are the soft- and hard-release method.

Soft release normally includes an acclimatization period; pre-release animal training, and post-release food supplementation (Resende et al., 2021). Whereas, hard-release is the direct release of individuals without any previous acclimatization, training or supplementation (Resende et al., 2021). In any case, planning in advance is required to decide the release site, the source of the animals, etc. (Adania et al., 2017). There are many questions about the uncertainty over the outcome of both the protocols. For example, the number of individuals to be released, the time dedicated to monitor and support released animals, etc. That is why is crucial to develop method that improve the decision-making reducing the uncertainty.

In general, wild caught individuals are normally hard released to avoid a prolonged contact with humans. this approach helps reduce habituation to humans, as well as risks of stress, injuries and disease transmissions (Resende et al., 2021).

Soft release can be performed followed by remote camera and radiotelemetry or GPS monitoring. As a matter of fact, camera traps strategically positioned inside the enclosure allow to monitor the animal 24h a day checking its activity level. There are several methods to evaluate the success of the animal conservation translocation programmes. The distance travelled by the animals immediately after the release can be a measure of success or failure depending on the biological characteristics of the species (Resende et al., 2021). In the first period after release, it is expected animal to travel for longer distances because they are exploring and learning about the characteristics of their new environment (Resende et al., 2021). However, if the animal increases its movements, eventually leaving and not returning to the release area, this could be interpreted as a failure, because the individuals did not establish themselves in the release area (Resende et al., 2021). Another metric is the body condition score: if body condition remains good after release, this could be a measure of success (Resende et al., 2021). Of course, if the animal gain weight after release, it is used as metric of successful evaluation. Survival, reproduction, population establishment and other behaviours may be better metrics, which should be used to infer conservation success.

By anchoring the species to the release site, it encourages homing behaviour that is one of the main purposes of the soft release protocol; as a matter of fact, this method increases site fidelity that would help for the monitoring of the animal as well and to check if the area is suitable for reintroducing new animals.

Just to make an example, in case of pumas, it is recommended that the release site be isolated and that a soft release protocol be followed. Additionally, the pumas should be fitted with radio-collars and monitored regularly after their release. Implementing environmental education initiative in the surrounding areas is also essential to raise local awareness and foster positive attitudes towards predators (Adania et al., 2017).

During long periods of captivity, it is common for animals to change their natural behaviour and develop some stereotyped behaviours (Adania et al., 2017). When the animal is transferred to the pre-release enclosure, a change in behaviour can be seen again, since the food is supplied at irregular times and the contact with humans is minimized (Adania et al., 2017).

Apparently, soft release is more successful than hard-release due to the behavioural management received by the animals prior to release. This is particularly true for terrestrial, captive-born and small animals because acclimatization prior to release would be important to reduce stress related problems, to increase body condition and to improve survival skills (i.e. anti-predator, social, food and locomotion training/learning). Nevertheless, hard-released animals will have better outcomes than soft-release for aquatic, wild-caught and large animals, because of the shorter time period of human contact (i.e. less stress-related and behavioural problems due to captivity and human contact) and greater amount of energy stored in its body considering the big size (slower metabolic rate) (Resende et al., 2021).

Ultimately, the choice of the protocol depends on the costs as well. The expenses must be proportional to the chance of success and to available funding; sparing money with the risk of high unsuccess is not worthing. Generally, soft-release methods tend to be significantly more expensive than hard-release methods (Resende et al., 2021).

2.2 Mark density estimation: Capture Recapture Method and Capture Mark Resight

Capture recapture method is a model to estimate abundance, based on retrapping of recognizable individuals by cameras. This provides robust, unbiased density estimates that are comparable across sites. However, this method is used with animals that have individually unique natural marketings or, in principle, to those for which a sample can be individually marked prior to camera trapping (Rowcliffe et al., 2008). Natural marks simplify the research; however, few species have natural markings sufficiently variable to recognize each individual like the stripes in felines or the whiskers in lions. It is also true to say that new approaches have been explored to address this issue, such as calculating the distance moved between captures, tracking how far an animal travels between each time it is captured, and independently measuring of home range size, which involves an estimation of the area in which an animal typically moves and lives (Rowcliffe et al., 2008). However, these methods raise some concerns regarding their reliability (Rowcliffe et al., 2008).

It is also important to recognize that individuals respond to one another and their physical environment and of course move independently of the camera (Rowcliffe et al., 2008).

The most basic model used is the Lincoln-Petersen model for a closed population of size N (an unknown parameter) (Pollock, 2000). Originally developed to estimate the size of a closed animal population, this method involves capturing, tagging and releasing as many animals as possible from a designed area at a given time (Tilling, 2001). So, in the first sample, all the animals are marked to differentiate one to another (*m*); then all animals are released again in nature. At a later time, the procedure is repeated: a sample of animals is captured and this time the sample is composed by both marked (*m*) and unmarked (*n*) animals (Pollock, 2000). Based on the proportion of marked animals captured, an estimation of the population can be measure. The formula used:

$$\widehat{N} = \frac{n1n2}{m2}$$

There are three important assumptions to consider: the first one is that the population is closed, meaning there is no immigration, emigration or birth resulting in no additions and deletions. The second is that all the animals have an equal likelihood of being captured in each sample. The third assumption to keep in consideration is that no marks are lost and all marked individuals are accounted for by observers (Pollock, 2000). A violation of these assumptions could lead to over or under estimation of the true population size (Tilling, 2001). However, capture-recapture studies have a long duration, rendering the closed models impractical (Pollock, 2000). Another important aspect to consider is behaviour response to capture, especially to the first. The capture probability on subsequent capture occasions changes, often greatly (White, 1982). If the recapture probability is lower compared to the first capture probability, the animals are exhibiting trap avoidance or trap shy. On the other hand, if the capture probability increases, animals are showing trap fascination or trap happy (White, 1982). Consequently, the estimate of *N* is based entirely on the first-capture information.

Captures probabilities vary by animal (differences in species, sex, age), but other types of variation in capture probability are not considered (social dominance, number and placement of traps in the home range, level of activity) (White, 1982). Because all these factors result in capture probabilities that vary among animals, this source of variation is defined as heterogenicity. For example, an active and socially dominant individuals may have high individual capture probability.

Mark recapture method is not the only one used; another method exists, and it is called Capture Mark Resight. Under the photographic mark-recapture framework, researchers non-invasively "capture" animals via photograph and identify individuals by their pelt pattern or other natural markings. After first capture by a camera trap, animals are considered "marked" based on unique natural characteristics. Encounter histories for marked individuals (i.e., those photographed at least once) are constructed for a series of recapture occasions from which detection probability and abundance can be estimated. Photographic mark-recapture studies have focused on a variety of felids with unique pelage patterns, including tigers (*Panthera tigris*), ocelots (*Leopardus pardalis*), jaguars (*Panthera onca*), leopards (*Panthera pardus*), snow leopards (*Uncia uncia*), and bobcats (*Lynx rufus*). Camera data are difficult to use in a mark-recapture framework when animals do not have unique pelage or other natural markings, because individuals cannot be identified by photograph alone. However, if researchers can physically mark some animals and individually identify the tagged animals with photographs, mark-resight models may be appropriate (Alonso et al., 2015).

In mark-resight studies, after the initial marking of individuals, there may be one or several resighting occasions in which marked animals are resighted, but unmarked animals remain unmarked and are counted as such. This distinguishes mark-resight from mark-recapture methods because no new marks are introduced during resighting occasions (Efford and Hunter, 2018). Indeed, sightings of previously marked animals can extend a capture–recapture dataset without the added cost of capturing new animals for marking. Combined marking and resighting methods are therefore an attractive option in animal population studies (Efford and Hunter, 2018). Starting with an initial capture and marking of animals, then researchers can conduct some surveys to resight marked individuals without recapturing them in order to track movements and behaviours. The combination of the two methods can lead to more accurate population estimates and stress reduction by reducing the need for handing animals.

To conclude, cameras can also be a valuable tool for monitoring animal captures. They can be placed inside the cages used for physically restraining animals, such as drop-floor cage or culvert cage. Promptly identifying when an animal is captured is crucial to reduce the time it spends in captivity, thereby reducing the risk of injuries and behavioural consequences. That is why GPS-equipped camera traps or other systems are crucial to send images in real time allowing for remote monitoring of the cage and making it possible to keep an eye on the situation from home or any location. Given that capturing an animal can be time-consuming, this approach enhances efficiency and welfare.

2.3 Unmarked density estimation: Random Encounter Method (REM)

Reliable assessment of animal populations is a long-standing challenge in wildlife management and conservation (Rowcliffe et al., 2008). Camera traps have been established among non-invasive methods for support wildlife monitoring programmes (Rowcliffe et al., 2008).

Unmarked camera trap density estimation methods represent an important class of models, especially useful when identifying animals is particularly challenging or time-consuming. In fact, unmarked animals make up the majority of species likely to be photographed.

One of the methods used based on camera traps to estimate population density (i.e. the number of individuals per unit area) without recognize animals is the Random Encounter Model (REM) (Rowcliffe, 2022). It describes the rate of contact between moving animals and static camera traps to estimate species density; as a matter of fact, a key assumption of the model is that cameras are placed randomly with respect to animal movement, meaning that they should not be targeted (Cusack et al., 2015).

The main advantage of this method is that the individual recognition is not needed, and therefore, it does not involve the capture of the animal to mark it. Furthermore, more than one species can be monitored during the same surveys because REM is not based on target species; it means that there is no need for the animal to be recorded at more than one camera to be identified.

It is based on modelling the process of random encounters between static camera and moving animals for the variables that affect the encounter rate. These variables are the camera detection zone, which consists of the radius of the effective detection zone and the horizontal angle of view; the distance travelled daily by the animals and the number of photographs from camera per unit of time. This is the formula used to estimate density from camera trap encounter rate (Rowcliffe, 2022):

$$D = \frac{Y}{H} * \frac{\pi}{v * r * (2 + \theta)}$$

Y describes the number of encounters, *H* the total camera survey effort, *v* represents the average distance travelled by an individual during a day, *r* and *ϑ* are the radius and the angle of the camera traps detection zone.

Two important aspects about the species to be considered: firstly, the speed of movement of the animal; secondly, the estimation of the daily activity level. For this reason, REM's application was limited because it is particularly challenging to make a good estimation of what is the day range of an animal (it requires telemetry or intensive behavioural observations), especially with large territory carnivores. However, in recent years new procedures have been developed and this does not represent an obstacle anymore (Rowcliffe, 2022). This method is a reliable alternative for monitoring wildlife populations especially when parameters (day range, detection zone, encounter rate) are estimated and the camera trap placements are appropriate.

The model assumes that cameras are placed randomly relative to animal movement, it means that cameras should be placed throughout the habitat used by animals rather than targeting specific features to attract them (Gilbert et al., 2020). The setting of cameras is determined a priori by precise geographical coordinates to avoid influences that could increase the capture probability. In fact, a computer-generated systematic grid with fixed spacing between them across a defined study area is provided by the team and web app.

REM is particularly recommended when the density of the animals is expected to change during the survey, since it provides an average density across the sampling period rather than a snapshot at a single moment. By considering the varying densities that may occur due to factors like animal movement or hunting pressure, REM provides a more comprehensive and reliable estimate of population density. This can help conservationists and researchers better understand how animal populations are impacted over time and make informed management decisions.

REM has been applied by the scientific community and citizen science project. Moreover, it has been proposed as a reference method for monitoring certain species at European level.

2.4 Shannon and Simpson index

Conservation policymakers may consider quantitative measures that compare diversity across ecological communities. To preserve and conserve animals, it is important to characterize the diversity within each community. A measure of species diversity should be applicable to any community independent of species abundance distribution. Two important definitions to focus on when talking about animals' diversity is the species richness and evenness. The first one is a count of the number of species occurring within the community and it is typically denoted by the symbol *S*. Higher the number of species, higher the richness. Species evenness refers to the equitability in the distribution of individuals among the species. The maximum species evenness would occur if each species in the community was equally abundant. Species diversity is defined by both species richness and evenness (Smith and Smith, 2012). On one hand, the simplest quantitative measure of community structure is the index of species richness, on the other hand species richness does not account for differences in the relative abundance of species within the community. For this reason, ecologists have addressed this shortcoming by developing mathematical indices of species diversity, which consider both the number and relative abundance of species within the community. One of these indices is the Shannon Index.

The Shannon index (*H*), also known as Shannon-Wiener index or Shannon entropy, is then computed as (Konopiński, 2020):

$$H = -\sum(pi)(Inpi)$$

pi: the proportion of the total individuals in the community represented by species *i*. ln is the natural logarithm. It quantifies the uncertainty in predicting the species of a randomly chosen individual from community. It accounts for both richness and evenness.

Shannon index's score goes from 0 to higher values with no theoretical upper limit. In the absence of diversity, where only one species is present inside a community, the value of H is 0. While, when more than one species is present the value is higher. Shannon's H considers the proportion of each species in an ecosystem studied; hence, it gives a better description of an ecosystem's diversity than a plain number of species. When the number of species is equal in two locations, the index is capable of distinguishing between sites dominated by a single or only a few predominant species and those where each species has comparable input to the whole biodiversity (Konopiński, 2020).

It is important to remember that Shannon index is strongly dependent on sample size. Indeed, the probability that all the alleles are sampled falls dramatically when the sample size is small.

Apart from Shannon index, other indices exist: Simpson's index measures the probability that two individuals randomly selected from a sample will belong to the same species (category).

The formula for calculating diversity is simply the sum of the square relative abundance (the proportion of a particular species in relation to the total number of individuals of all species within a community) of different species:

$$D = \sum pi^2$$

Values range from 0 (infinite diversity) to 1 (no diversity), with lower values suggesting greater diversity, with more species being present in similar abundances.

This index is often referred to as the Dominant index because it emphasises the dominance of species within a community. Another formula exists and it can be used:

$$D = \sum ni(ni-1) \, / \, N(N-1)$$

While both formulas serve similar purposes, the first one is used for infinite population, while the second is more suited for defined populations.

Moreover, the Simpson index divides in Simpson diversity index and Simpson reciprocal index. They provide different perspectives on community structures even if both are measure of biodiversity. This Simpson diversity index is calculated as:

$$1 - D$$

In this case, this value refers to the probability that two individuals randomly selected from a sample will not belong to the same species (category).

The Simpson reciprocal index:

$$1/D$$

It provides a value that reflects the effective number of species in the community in a more intuitive way, meaning that higher value suggests a community with more species or a more equitable distribution of individuals among species. As a matter of fact, values range from 1 to infinity, meaning that the lowest value for this index is equal to 1 and the highest corresponds to the number of species. Having not upper limit, it is potentially more informative for comparing diverse community.

Shannon's and Simpson's indices are now regarded as being members of the same family of indices, with some differences. The Shannon index is more sensitive to rare species and can reflect changes in community composition more effectively. The Simpson index is more sensitive to dominant species, making it useful in understanding the impact of dominant species on community structure.

Both Shannon's and Simpson's indices have truly stood the test of time and are still generally regarded as the premier measures of ecological diversity (Konopiński, 2020) helping to define wildlife management and conservation actions.

CHAPTER 3: THE USE OF CAMERA TRAPS FOR REINTRODUCING A FEMALE OCELOT (CASE STUDY)

3.1 Introduction

I spent six weeks in Alturas Wildlife Sanctuary, a wonderful wildlife rescue and rehabilitation centre in Costa Rica.

In this period, I had the pleasure to develop a personal project about the use of camera traps for the release of a female ocelot present in the rescue centre. In Alturas Wildlife Sanctuary, apart from the Sanctuay where are hosted the animals that cannot be released anymore in the nature because they do not fit the characteristics necessary to survive into the wild, there is the Clinic where almost everyday animals arrive taken by locals or SINAC (Sistema Nacional de Areas de Conservación, National System of Conservation Area); the Nursery, where babies are looked after with extreme care and the Pre-release. This latter is a secluded place away from human noise and visibility, accessible only to authorized personnel responsible for feeding the animals and maintaining their enclosures. It is mandatory to wear a red mantel to prevent imprinting on the animal; the choice of red is intentional, as it is an uncommon colour in nature, making it unlikely that an animal would associate a red figure with food once released into the wild. This helps ensure that they do not connect human presence with feeding.

In the pre-release phase, an adult female ocelot was undergoing rehabilitation to regain her strength for eventual release into the wild. She was discovered alone and injured at the corner of a street when she was about five months old, raising concerns about what might have happened to her mother.

Unfortunately, I was not able to witness her reintroduction, but I am glad to have collaborated for its release.

3.2 Ocelot biography

Ocelots are solitary and nocturnal animals. Their weight is around 5,4- 11,4 kg and their length is from 65- 97 cm. These animals are polygynous, and the litter size is 1 to 2 altricial kittens. By the age of one-year kittens are independent considering that they start to learn from their mother how to hunt at a few months old. Small and medium size animals like rabbits, birds, reptiles, amphibians are hunted by stalking and pouncing by ocelots that can hunt in trees, on the ground or along stream (Magalhães and Srbek-Araujo, 2022).

The spot pattern of each ocelot is unique, serving as natural form of identification. This distinctive marking allows for individual recognition of each animal.

Their home range depends a lot on the habitat and the sex: sex is an important intrinsic factor affecting the spatial ecology of solitary carnivores (Borrajo, 2016). As a matter of fact, female's home range is around 8,36 km^2, while male's home range is around 16,1 km^2. Males have larger home ranges (thus exhibit longer daily movements) than females and being polygynous their territory overlap the 56% territory of the primary female. Moreover, in case of dense vegetation their home range tends to be smaller, on the other hand in case of scarcity of prays, their home range tends to be bigger (Magalhães and Srbek-Araujo, 2022). Activity peaks occurred near midnight (Herrera et al., 2018). Flexibility in ocelot spatial patterns permitted a dynamic response to prevailing ecological and social environments (Tewes, 1986).

Usually, solitary carnivore species are characterised by the rarity of direct contact between adults of the same sex except during the mating period (Borrajo, 2016).

Both sexes may disperse, even if dispersal is more common in males that move greater distances (Borrajo, 2016).

3.3 Observational applications of camera traps and species diversity calculation

In Alturas Wildlife Sanctuary, another Wildlife Intern had initiated the project before my arrival. Once got there, I chose to continue her project, as additional data were needed for a more accurate estimation of the species diversity in the area under investigation.

We analysed an area of 65 hectares, equivalent to 0,65 km², positioning in total 18 camera traps at various locations and times. The intern who arrived before me positioned 11 camera traps, while I placed 7. Since she spent a longer time in Costa Rica, she was able to collect more data.

The area analysed was twenty minutes far away from the rescue centre and the landowner has a good relationship with Alturas; as a matter of fact, they have collaborated for some other projects.

With the support of a volunteer coordinator or the keeper of the rescue centre, I placed the camera traps in areas where no poachers have previously been found, close to water sources and where footprints or animal traces were present in the path. I have marked the coordinates of each camera traps using a GPS to identify the precise spot of each device.

I spent six weeks Costa Rica, but I positioned all the cameras two and a half weeks after my arrival. Initially, I needed to organize my project with the centre's manager, then I encountered some issues with the cameras. Since the devices were still in the jungle recording animal videos, many were wet from the rain when I first visited the property to relocate them. This was during the rainy season in Costa Rica. As a result, I had to place the cameras in a dry room for several days, which delayed the start of my project and impacted the amount of data I could collect during the final three weeks. Fortunately, after few days, cameras begun functioning again. In Alturas Wildlife Sanctuary there were no other camera traps available because other Wildlife Interns were using them for other projects.

I used Wosoda trail camera with alkaline batteries. I set up high quality videos of thirty seconds each.

I positioned cameras around trees at a hight of around 40 cm from the ground. Every week I went there to change the batteries if necessary and to collect the sim card to analyse the videos recorded. It took a while before really understand the correct positioning of the cameras, as many activations were triggered by the movement of leaves rather than by animal activity. In total, I examined more than a thousand of videos. In addition, sometimes I found that the sim card was completely empty because the cameras did not record anything during the week; it could have been due to some mechanical problems or an incorrect set up of the camera. Consequently, the data I collected were insufficient for a valid species diversity calculation. However, by combining my findings with the data gathered by the intern before me, we achieved a successful outcome. Of course, more data would be necessary to accurately determine the wellbeing of them ecological system and whether the area could be suitable for the reintroduction of the ocelot.

The aim of my project was to assess the species diversity that is given by both the species richness and evenness. The species richness is defined as the number of different species in an area, it is an indicator of the relative wealth of species in a community (Peet, 2024); this is the oldest concept of diversity (Peet, 2024) and the simplest quantitative measure of community structure. However, species richness does not account for differences in the relative abundance of species within the community. For this reason, it is important to calculate both the species richness and the species evenness that measures how evenly distributed the species are in a community.

I created a rank abundance curve to illustrate the most representative species within the community. This tool is commonly used by ecologists to examine patterns of relative abundance among the species involved. In the graph, species are arranged from the most to the least abundant, allowing for the visualization of species richness- represented by the number of different species on the chart-, and species evenness indicated as the slope of the line that fits the data. A steep slope suggests low evenness, a shallow slope indicates high evenness as the abundances of different species are similar.

At the end, the total amount of videos of individuals that we have recorded are 448 including: Peccary, Agouti, Great Curassow, Deer, Coati, Ocelot, Tayra, Puma, Coati, Bat, Great Tinamou, Common opossum, Coyote, Striped hog nosed skunk, Tamandua, Agouti, Bird, Helmeted iguana and Hummingbird. Table 3.1

Species	Sum of Quantity	Sum of Unidentified	Sum of Females	Sum of Males
?	2			
Agouti	62	38	12	12
Bat	4	4		
Bird	1	1		
Coati	32	16	1	15
Common opossum	3	2	1	
Coyote	3	2		1
Deer	30	10	2	19
Great Curassow	55		26	29
Great Tinamou	4	4		
Helmeted Iguana	1	1		
Hummingbird	1	1		
Ocelot	11	1	2	8
Peccary	218	106	56	56
Puma	7			6
Striped hog nosed skunk	3	2	1	
Tamandua	3	1		2
Tayra	8	8		
Totale complessivo	**448**	**197**	**101**	**149**

Table 3.1 Pivot Table

In my Rank abundance diagram, Peccaries, a pig-like ungulate of the family Tayassuide had while the Hummingbird, belonging to the Trochilidae family, had the lower abundance: 218 individuals against 1. Fig 3.1.

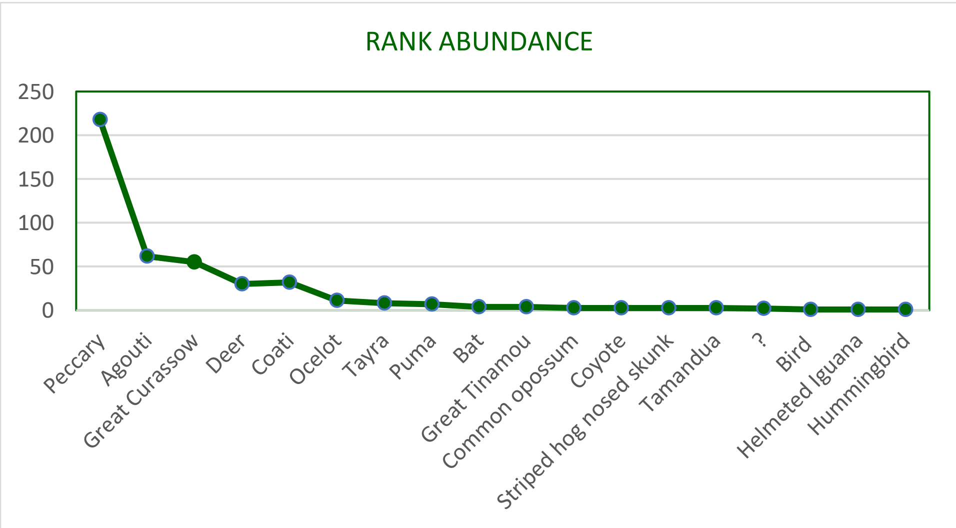

Figure 3.1 Rank abundance curve

To calculate the species diversity, several indices can be used. I chose to calculate both the Shannon index and the Simpson index. The Shannon index is calculated as follows:

$$H = -\sum[(Pi) \times \ log(Pi)]$$

Pi represents the proportion of the total individuals in the community belonging to species *i*.

In the absence of diversity when just one species is present in the entire area, the value H is 0. It is based on the idea that greater diversity corresponds to greater uncertainly in randomly choosing a specific species. Choosing randomly two individuals there is low probability that they belong to the same species.

In this case study, I calculated the Shannon index and the value was H= 1,76. Table 3.2

Species	**abundance**	**Pi**	**Ln(Pi)**	**Pi * Ln(Pi)**
Peccary	218	0,486607143	-0,72029817	-0,35050223
Agouti	62	0,138392857	-1,977658847	-0,27369386
Great Curassow	55	0,122767857	-2,097460047	-0,25750068
Deer	30	0,066964286	-2,703595851	-0,18104437
Coati	32	0,071428571	-2,63905733	-0,18850409
Ocelot	11	0,024553571	-3,70689796	-0,09101758
Tayra	8	0,017857143	-4,025351691	-0,07188128
Puma	7	0,015625	-4,158883083	-0,06498255
Bat	4	0,008928571	-4,718498871	-0,04212945
Great Tinamou	4	0,008928571	-4,718498871	-0,04212945
Common opossum	3	0,006696429	-5,006180944	-0,03352353
Coyote	3	0,006696429	-5,006180944	-0,03352353
Striped hog nosed skunk	3	0,006696429	-5,006180944	-0,03352353
Tamandua	3	0,006696429	-5,006180944	-0,03352353
?	2	0,004464286	-5,411646052	-0,02415913
Bird	1	0,002232143	-6,104793232	-0,01362677
Helmeted Iguana	1	0,002232143	-6,104793232	-0,01362677
Hummingbird	1	0,002232143	-6,104793232	-0,01362677
Grand Total	**448**			**-1,76251913**

Table 3.2 Shannon Index calculation

The Simpson index is calculated as:

$$D = \sum ni(ni - 1) \; / \; N(N - 1)$$

Dominance is the converse of diversity. In fact, the basic Simpson index it is often used as a measure of dominance being more sensitive to changes in the most common species. D value ranges from 0 to 1, where 1 represents complete dominance, so just one species present in the community (Smith and Smith, 2012). It is important to highlight that even if dominance is typically assumed to mean the greatest in number, abundance alone is not a sufficient indicator of dominance. Dominance can be defined based on some combinations of characteristics that include both the number and the size of the animals.

In this case study, I have calculated the Simpson index:

Species	n	n-1	n(n-1)	N(N-1)	n(n-1)/N(N-1)
Peccary	218	217	47306		
Agouti	62	61	3782		
Great Curassow	55	54	2970		
Deer	30	29	870		
Coati	32	31	992		
Ocelot	11	10	110		
Tayra	8	7	56		
Puma	7	6	42		
Bat	4	3	12		
Great Tinamou	4	3	12		
Common opossum	3	2	6		
Coyote	3	2	6		
Striped hog nosed skunk	3	2	6		
Tamandua	3	2	6		
?	2	1	2		
Bird	1	0	0		
Helmeted Iguana	1	0	0		
Hummingbird	1	0	0		
Grand Total	**448**		**56178**	**200256**	**0,280531**

Table 3.3 Simpson index calculation

D= 0,28

Moreover, I measured other Simpson indexes such as the Simpson's diversity index equal to:

$$1 - D$$

The higher the value, the higher the diversity of species. In this case, D= 0,72.

Simpson's reciprocal index is equal to:

$$1/D$$

In this case, the lowest value for this index is 1 and the highest value corresponds to the number of species. The higher the value, the higher the diversity. D= 3,59.

In this case study, peccaries introduce a bias for the calculation of the species diversity due to their significantly higher abundance compared to other species in the community. To address this, I tried to calculate the species diversity without including peccaries, allowing for a clearer comparison of the results. Without Peccaries, the Shannon index is equal to H= 2,08, indicating a higher level of species diversity. Similarly, the Simpson index, excluding Peccaries, yields D= 0,16. Since the value is closer to 0 than to 1, it also suggests a higher species diversity in this scenario. In any case, it is essential to consider the environment as a whole when assessing biodiversity. Therefore, peccaries should be included in the analysis, as their population play a significant role in the ecosystem. In addition, if improper camera trap positioning resulted in the oversampling of peccaries, we would need to remove them from the analysis. However, this is not the case here, as peccaries genuinely represent the highest abundance.

In the video that have been recorded, I saw very closely a Puma (Puma Concolor costaricensis). It had already been seen previously, but there is no certainty that it was the same individual. In any case, the animal was very thin, much more compared to the ocelot present in the area. The two species of animals have a slightly different type of diet. A research has found out that pumas overlap with a number of medium to large prays including deer, ant eaters, armadillos, brocket deer and peccaries; while ocelot overlap mainly with small to medium preys like opossum, armadillos and raccoons (Herrera et al., 2018). In addition, it is very important to highlight that both these animals have large plasticity in their diet, consequently they adapt to declining availability of primary prey by prey switching. In any case, when diet overlap, they become competitor; this aspect it is not particularly worrying in the area investigated because of the abundance of prays. Moreover, different activity peaks or spatiotemporal differences in the activity schedules of predators might contribute to their coexistence in this area. Therefore, further investigations over a larger area should be conducted to assess prey abundance and the presence of other feline individuals.

3.5 Case study conclusion

There are several important considerations to take into account. The species diversity of the area suggests that many species inhabit the territory, with most of these animals constituting a part of ocelot's diet. However, big size animals or potential competitors, such as Puma Concolor constaricensis Figure 3.1 or other Leopards Pardalis, are also present. Considering that the images have captured the presence of both species, it is necessary to assess whether the area is sufficiently expansive to support their coexistence without leading to competition.

In addition, the area investigated covers just a small part of an ocelot's home range; in fact, species diversity in a wider area should be calculated to understand the abundance of prey availability placing camera traps at different height to check the presence of rodents or smaller species that represent part of ocelot's diet.

Calculating the species diversity is crucial for analysing the prey-predator balance, helping to determine if there are sufficient resources for the animal being reintroduced. Moreover, when selecting a release site, it is important to assess the availability of water sources. In this area, several suitable spots were identified.

In some videos, I observed the presence of poachers in the area. Conversations with the Costa Rican keeper of Alturas Wildlife Sanctuary revealed that hunting was legal in Costa Rica a few decades ago. Conservation effort did not gain widespread attention until later in 20th century (Maguire, n.d.). Due to significant decline in wildlife and growing concerns for conservation, there is now a strong negative attitude towards hunting, especially for sport and commercial purposes. Hunting and wildlife trade are largely prohibited under the amended Wildlife Conservation Law (N° 7317) (Maguire, n.d.). However, wildlife has long been hunted for subsistence and people continue to hunt out of tradition, even if they do not require bushmeat for subsistence. Researches have shown that commonly hunting species such as tapirs and peccaries were significantly less abundance outside national parks like the Corcovado National Park where they receive better protection from hunting (Maguire, n.d.). Poachers are interested in hunting peccaries to sell their meat to those accustomed to eating it or just for personal consumption. This is why camera traps have frequently recorded the presence of poachers in the area I was investigated, which is notably rich in peccaries.

Another aspect to consider before releasing the ocelot is the tracking of other ocelots in the area. Additional analyses should be conducted to accurately identify these individuals and avoid overestimating their presence. Notably, the other ocelots observed were in shape, particularly when comparing to the body condition of the puma present in the territory. As a medium-sized carnivore with relatively small home range sizes, ocelots have lower energy requirements and a broad diet. These factors may facilitate their movement across various land uses, making them more adaptable than larger carnivores. In fact, compared to puma and jaguars, ocelots have the smaller home range size; moreover, considering that female have a smaller home range compared to males, the reintroduction of the ocelot in the Pre-release area at Alturas Wildlife Sanctuary is particularly promising.

Of course, much more analysis over a larger area should be conducted to evaluate the feasibility of releasing the animal considering its home range requirements.

Figure 3.1 Puma Concolor costaricensis recorded by the fifth camera trap present in the area investigated, Dominical Costa Rica.

CONCLUSION

Camera traps use is challenging but is essential, especially in light of the significant loss of biodiversity. Even though their usage is regulated differently across countries due to the non-existence of a common law in force, these devices are widely employed around the globe. There are various models and setups depending on the specific project, but the most crucial aspect remains the quality of the images obtained. Often, you may end up with thousands of videos of leaves swaying in the wind, but capturing just one glimpse of the target animal makes all the hard work worthwhile.

Camera traps have been utilized for many years and remain a vital tool in most conservation projects; innovations in technology continue to enhance their effectiveness, leading to always better results in wildlife monitoring and research.

My experience with the camera traps has taught me the value of patience. Animals are living beings that typically avoid the human presence, but these devices allow us to study their behaviour, habits and lifestyles in the absence of human interference.

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