UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Colegio de Ciencias Biológicas y Ambientales

Assessment of the reintroduction process of a captive-raised jaguarundi in Bosque Protector La Perla, Ecuador

Gabriela Pacheco Flores

Biología

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RESUMEN

El jaguarundi (Herpailurus yagouaroundi) es un gato pequeño que se considera una especie casi amenazada en Ecuador. Por tanto, el establecimiento de estrategias de conservación es fundamental para mantener poblaciones silvestres viables. La reintroducción es un enfoque de conservación frecuente que consiste en la transferencia y liberación intencional de uno o más individuos en su rango de hábitat indígena. En este estudio, evaluamos el proceso de reintroducción de un jaguarundi nacido en la naturaleza, pero criado en cautiverio. El individuo fue incautado por posesión ilegal de un dueño cuando era de un mes. Luego, se mantuvo en instalaciones que se asemejan a su hábitat natural con interacciones humanas minimizadas hasta la edad de 27 meses. Una vez que el animal demostró estar sano, competente e independiente, fue expuesto a un proceso de liberación blanca de 87 días en Bosque Protector La Perla, Ecuador. El jaguarundi fue liberado el 15 de abril de 2020. El seguimiento se logró mediante GPS-collaring. Los datos obtenidos indicaron que el individuo mostró un comportamiento similar al registrado en jaguarundis silvestres, durante la pre y post liberación. El animal exhibió un patrón de actividad bimodal, usó hábitats perturbados por humanos, como zonas agrícolas, con frecuencia, y pudo alimentarse por sí mismo. Este estudio es importante por lo que es el primer informe del monitoreo posterior a la liberación de un jaguarundi a través del sistema GPS en un bosque tropical húmedo protegido, La Perla, que proporciona información valiosa para futuros programas de reintroducción de jaguarundis.

Palabras clave: Criado en cautiverio, collar GPS, felidae, jaguarundi, monitoreo, reintroducción, liberación blanda, paisajes perturbados por humanos

ABSTRACT

The jaguarundi (*Herpailurus yagouaroundi*) is a small cat that is considered a Near Threatened species in Ecuador. Thus, the establishment of conservation strategies is essential to maintain viable wild populations. Reintroduction is a frequent conservation approach that consists of the intentional transfer and release of one or more individuals in their indigenous habitat range. In this study, we assessed the reintroduction process of wild-born but captive-raised jaguarundi. The individual was seized for illegal possession from an owner as a kitten. Then, it was kept in facilities resembling its natural habitat with minimized human interactions until the age of 27 months. Once the animal proved to be healthy, competent and independent, it was exposed to an 87-day soft-release process in Bosque Protector La Perla, Ecuador. The jaguarundi's release date was April 15th, 2020. Monitoring was achieved through GPS-collaring. The data obtained indicated that the individual displayed a behavior similar to the one recorded in wild jaguarundis, during pre- and post-release. The animal exhibited a bimodal activity pattern, used human disturbed habitats, like agricultural zones, frequently, and was able to feed for herself. This study is important as it is the first report of a jaguarundi's post-release monitoring through GPS-system in a tropical humid protected forest, La Perla, providing valuable information for future jaguarundi reintroduction programs.

Keywords: Captive-raised, GPS collar, felidae, jaguarundi, monitoring, reintroduction, soft-release, human disturbed habitats

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INTRODUCTION

The jaguarundi (*Herpailurus yagouaroundi*) is a small to medium sized diurnal felid characterized by its slender, elongated body with a long tail and a narrow, mustelid-like head. Its face is framed by a small, slim head, with small round ears and a short snout (Giordano, 2016). The species is distinguished from other neotropical cats because of their body and uniform coloration, usually found in variations that range from red, to almost black, intermediates of brown, grey and yellowish tones (Caso & Oliveira, 2015). They show also reclusive but aggressive traits. Although jaguarundis mostly hunt on the ground, they have demonstrated to be efficient climbers and swimmers (Giordano, 2016). The species is ecologically important as it provides ecosystem functions such as maintenance of structure and composition of biological communities through the control of herbivore populations because they are generalist predator of small vertebrates (Boron, Xofis, Link, Payan, & Tzanopoulos, 2020). It is a widely distributed small cat that ranges from southern Texas in the United States to northern Argentina, inhabiting open and closed lowland formations such as savannas, deserts, semi-arid thorn scrub, restinga, swamp, primary and secondary lowland humid and montane forests (where they are broadly found in Ecuador), and even human-disturbed environments (Caso & Oliveira, 2015; Espinosa et al., 2018; Woolf, Sunquist, & Sunquist, 2003). Despite the IUCN declaring the jaguarundi a Least Concern species, it has been proved that it is an uncommon felid with a decreasing population trend as its abundance and population densities are considerably low (Caso & Oliveira, 2015; Kasper, Schneider, & Oliveira, 2016). The main threats to the jaguarundi include natural competitors, habitat loss and fragmentation as a consequence of human activities, and human-wildlife conflict (Caso & Oliveira, 2015; Kasper et al., 2016). Thus, the establishment of conservation strategies is essential to maintain viable wild jaguarundi populations (Caso & Oliveira, 2015).

Wildlife reintroductions are a frequent conservation approach that consists of the intentional transfer and release of one or more individuals in their native habitat range, where the species has disappeared or diminished. Its aim is to promote viability of wild populations that had been affected by external pressures (Minterr & Collins, 2010). Reintroductions require a thorough planning process to meet the species needs and allow the individual's long-term survival. The decision to reintroduce animals is made upon its goal of conservation and the population status. Further design involves risk and feasibility assessments to define the release site, the release methods (soft-release or otherwise), as well as a follow up monitoring program to evaluate the success of the release in terms of individual survival and welfare (Davis, 1983; Minterr & Collins, 2010). In fact, successful approaches include pre-release training of the animal, acclimation, monitoring, local employment, and community education (Houser, Gusset, Bragg, Boast, & Somers, 2011; Thorne, Olney, Mace, & Feistner, 1996). Reintroductions have been successful among different large felid species, including tigers (*Panthera tigris tigris*), lions (*Panthera leo*), leopards (*Panthera pardus*), cheetahs (*Acinonyx jubatus*) and pumas (*Puma concolor*), as well as with small cat species such as servals (*Leptailurus serval*), bobcats (*Lynx rufus*) and Eurasian wildcat (*Lynx lynx*) (Adania, de Carvalho, Rosalino, de Cassio Pereira, & Crawshaw, 2017; Baker, Warren, Diefenbach, James, & Conroy, 2001; Hayward et al., 2007; Linnell, Breitenmoser, Breitenmoser-Würsten, Odden, & Von Arx, 2009; Straten et al., 2019; Soorae, 2018). Hence, the reintroduction of jaguarundi individuals might constitute an effective conservation strategy for populations of this carnivorous species across its native home range. Even so, the reintroduction of captive-raised jaguarundis presents many challenges inherent to the species and derived from human-disturbance habitat changes as well as human-wildlife conflict (Caso & Oliveira, 2015; Kasper et al., 2016).

Reintroduction success is determined by several factors, including inter- and intraspecific competition (Eastridge & Clark, 2001). Therefore, one of the main threats to the jaguarundi's survival is the ocelot (*Leopardus pardalis*), which has been associated with the decrease of jaguarundis (Caso & Oliveira, 2015; Cruz et al., 2018; Giordano, 2016; Kasper et al., 2016). The origin of the relocated individual also plays a fundamental role as it has been demonstrated that the reintroduction of captive-raised animals exhibits a lower probability of success in comparison to wild-caught animals (Fàbregas, Fosgate, & Koehler, 2015; Fischer & Lindenmayer, 2000; Jule, Leaver, & Lea, 2008). It is suggested that this happens due to captive-raised animals displaying behavior deficiencies in their hunting skills, inter- and intraspecific interactions and reproduction (Fàbregas et al., 2015; Vickery & Mason, 2003). To the best of our knowledge, there are no published studies regarding the behavior of captive-raised jaguarundis but the above-mentioned deficiencies have been refuted with similar species. For example, it was determined that captive ocelots maintained some behavioral patterns as they displayed stereotypic pacing, but they were also less active than their wild counterparts and showed diurnal habits when the species is nocturnal (Weller & Bennett, 2001). Nonetheless, these difficulties can be overcome as evidence has shown that animals, including other neotropical felids, such as the puma, are able to develop behavioral skills and ecological patterns close to those described in wild animals after exposure to acclimation periods, even when raised in captivity (Adania et al., 2017; Davis, 1983; De Milliano, Di Stefano, Courtney, Temple-Smith, & Coulson, 2016; Fàbregas et al., 2015; Minterr & Collins, 2010).

Another key factor that influences reintroduction success is the release site as locations with refugia and low environmental variation increase survival rates (Eastridge & Clark, 2001). It is considered that anthropogenic habitat changes such as agriculture, pastures, border fencing, transportation corridors, and domestic animals may become threats to the reintroduced animals at the release sites (Caso & Oliveira, 2015; Whittley, 2014). In fact, habitat loss and fragmentation negatively affect jaguarundis by causing population decrease (Cruz et al., 2019). However, this species has shown high environmental flexibility which allows it to adapt to moderate anthropogenic disturbances which are frequent in mosaics of tropical forest and human-modified landscapes that include agriculture, grassland, and moderately urbanized areas (Coronado Quibrera et al., 2019; Cruz et al., 2019; Espinosa et al., 2018). It has been suggested that mosaics may benefit jaguarundis because their prey are present at higher densities in comparison with less fragmented locations (Coronado Quibrera et al., 2019; Cruz et al., 2019). At the same time, studies have shown that jaguarundis avoid pastures and direct human disturbance, even when they reside in forested habitats neighboring urban locations (Boron et al., 2020). One possible reason is that the jaguarundi is subject to human-wildlife conflict as pre-emptive or retaliatory persecution because it feeds on poultry, as a victim to incidental felid hunting or poaching when they fall into traps intended for other neotropical felids, during collisions with vehicles, confrontations with domestic dogs or livestock, or after habitat loss (Adania et al., 2017; Caso & Oliveira, 2015; Giordano, 2016; Loveridge, Wang, Frank, & Seidensticker, 2010). Surviving felids from human-wildlife conflict are often kept in captivity until they fully recover and are competent enough to be survive in the wild. Unfortunately, it is not uncommon that these individuals are recaptured soon after their release due to complications from human-wildlife conflict, such as the mentioned above (Adania et al., 2017).

Regardless of the knowledge that reintroduction success can be limited by the influence of anthropogenic factors, it is key to relocate animals to their native home ranges, when possible (Minterr & Collins, 2010). This is because reintroductions contribute to species conservation through the replenishment of its populations, which is needed as natural recolonization of the same species tends to be slow (Briers-Louw, 2017. Other reintroduction benefit is the restoration of ecosystem structure and function (Briers-Louw, 2017; Fischer & Lindenmayer, 2000; Jule et al., 2008). The selection of release sites is crucial for quality of life and individual survival after reintroduction. Release sites must fit in with the distribution range, habitat preference, ecology, and adaptability of the reintroduced species (Minterr & Collins, 2010; Stadtmann & Seddon, 2018). The jaguarundi is a native species for Ecuador, where its presence has been registered in the coast as well as in the Amazon and the lowland Andes (Tirira, Brito, Burneo, & AEM, 2020). In Ecuador, it inhabits tropical moist forests, deciduous forests, subtropical forests, and submontane evergreen forests that range from 0 to 1800 meters above sea level (Vallejo, 2018). Individual sightings have been confirmed in the tropical rainforest of the Choco Andino for the jaguarundi and other felid species (Tirira et al., 2020). However, this small cat is considered a Near Threatened species in Ecuador due to its population decreases; this concern might soon move the jaguarundi to either the Vulnerable or Endangered category (Amador, Espinosa, & Tirira, 2011).

Here we assess the reintroduction success of a wild-born but captive-raised jaguarundi to the protected moist forest located in Bosque Protector La Perla, Ecuador (La Perla, hereafter). We compared the post-release activity of the jaguarundi with its pre-release enclosure to study the ecological features and human-wildlife interactions of reintroduced jaguarundis in human-disturbed areas. To the best of our knowledge this is the first report of a soft release of a jaguarundi with a follow-up monitoring performed using GPS collar technology and camera trap data in La Perla, the release site. As such, the resulting information will be useful for future reintroduction programs. Also, it will contribute to address the growing nature of human-wildlife conflict affecting small cat conservation in Ecuador. The objectives of this study are to 1) evaluate if it is possible to successfully introduce captive-raised jaguarundis in human-dominated landscapes, 2) compare the behavior and activity of the captive raised jaguarundi with existing literature on wild populations, as well as 3) determining which tools and approaches can be used to increase their chances of survival.

METHODS

Jaguarundi Origins and Pre-reintroduction Process.

The jaguarundi in this study was seized from an owner for illegal possession in the province of Esmeraldas, canton of San Lorenzo, Ricaurte parish in Ecuador and brought to Tueri Animal Hospital, Quito on January 26th, 2018. It was approximately one month of age, female, weighing 364 grams, and had a brown morph coat. Initial clinical findings showed that it suffered severe dehydration, diarrhea, poor body, and coat condition. It received the pertinent medical care by two veterinarians. As part of the jaguarundi rehabilitation process, it was introduced to a domestic cat of the same age as an aid to create an imprint. This is crucial for the development of mammals as it is a type of identity and learning behavior, in which individuals narrow their social preferences to an object during this stage, contributing to the develop of social skills (Mccabe, 2013). Contact with humans was minimized, to assure the jaguarundi's wellbeing and independence as a wild animal. In April, the cat was relocated to Yanacocha Animal Rescue Center in Tena Puyo, Pastaza, for approximately six months. In October, it was relocated to the Nueva Loja Tourist Park, Lago Agrío, Sucumbios, Ecuador where it remained for approximately one year. By that time, it had shown no dependence on humans, abilities to look for shelter, good climbing and hunting skills and agility, as well as behavioral features similar to its wild counterparts. Finally, the jaguarundi was transferred to the release site in La Perla when it was 27 months old, weighing 4.48 kilograms and in perfect health.

Diet in Captivity

While in captivity, the jaguarundi's dietary plan varied throughout its developmental stages (Table 1). There are slight changes, mostly in food consistency from nursing to weaning off milk. As a fully mobile and strong juvenile, it was given live prey through a sleeve at a setup schedule to reduce human interaction and promote the development of hunting skills. The adult individual was considered self-sufficient in killing live prey, as caregivers provided a bigger variety of large animals, which it was able to feed upon with no difficulties, as well as whatever prey that crawled, flew, or fell into the enclosure.

Table 1: Dietary plan of jaguarundi at different life stages in captivity

Life stage	Dietary plan
Nursing kitten	KMR® Powdered Milk Replacer for Kittens | PetAg
Weaning kitten	Starter Mousse & baby dog Wet Royal Canin
Juvenile	Live prey: guinea pig, quail, rabbit and fish
Adult	Live prey: guinea pig, quail, rabbit, fish, additionally what was placed and crossed inside the enclosure.

Reintroduction Site and Study area

La Perla is a protected forest located close to 40.6 kilometers North from the city of Santo Domingo de los Tsachilas, 4 kilometers Southwest of the town Concordia, along he La Concordia-Esmeraldas road. The majority of the reserve is surrounded by a rarely used road to the east, and agricultural areas to the south and west, where there is little to no permanent human settlements. Its 650 hectares are divided into subregions with different land use: 286-ha of forest cover with layers of varied floristic diversity, bamboo, guadua and palm areas, pastures (flat land), broken terrain extents, irrigation canals that lie straight across one edge of the forest, pepper and banana crops with a resting turnover for new cultivations of banana, buffer zones between the cultivations and the main forest block, wetlands and streams, and a station of cultivation of African palm (INIAP) at the end of the south perimeter (Fig. 1). This protected forest is a conservation priority for owner Suzanna Sheppard, and the Susan Sheppard Foundation maintain institutions at this side such as the Center for Environmental Education an Interpretation, a refuge for species of both flora and fauna that have been affected frontline in deforestation (Bosque La Perla, 2020). La Perla is one of the last remnants of the Chocó tropical humid forest due to habitat destruction by anthropogenic causes, and fits a similar ecology to the jaguarundis habitat range. Since 1992, birds, porcupines, reptiles, jaguarundis, ocelots, and other species have been released into the reserve. Camera trap studies have shown stable populations of peccaries, small felids, howler monkeys, and even crab-eating racoons. Based on this information and the collaboration of the team at La Perla, this protected forest was considered ideal for the reintroduction site for this jaguarundi.

Soft Release Process

Initial release date and location were changed due to the novel Coronavirus introduced into the country on February 29th, 2020 according to the Ecuadorian Ministry of Health. For that reason, El Chocó Biosphere Reserve, which was the original primary forest selected as the release site due to its remoteness, remained closed. Revisions were made and the soft-release and monitoring site was changed to Bosque Protector La Perla. A soft-release enclosure was built in a isolated forest in La Perla, without altering the habitat or forest ecosystem. The dimensions were 6 meters wide x 8 meters long x 2 meters high with a ceiling mesh installed that included shrubs and trees, but also allowed small animals to pass through (Fig. 2). The enclosure was constructed with 2x2 meter welded mesh enclosure walls. The enclosure was equipped with a platform, as the jaguarundi’s resting or sleeping area, with a trap door, in case she needed to be captured for any medical reason (Fig. 3). A 2 m^2 pool was installed with small wooden structures and rocks to mimic a natural scenario to hunt fish such as Pacific fat sleeper (*Dormitator latifrons*) and catfish (*Bagre* sp.) The individual was placed into the soft-release enclosure on January 19th, 2020 after spending 4 days in a temporary enclosure to ensure its full mobility and attentiveness after it arrived from Tueri Animal Hospital, Cumbaya, Quito. During the soft-release process, the individual was given water and food through a PVC tube 6 days per week at regular feeding times, between 17:00 and 20:00 to eliminate human interactions.

Camera traps were set-up to monitor the jaguarundi both inside and outside of her enclosure. There were 8 cameras in total, 4 to view inside and 4 to view the outside perimeter. These captured and monitored 100% of the interior and exterior of the enclosure, registering different animals that came near to or around the area. Food was put in the enclosure after her release to aid in diet if needed. Camera traps were maintained in place even after the jaguarundi's release to monitor these feeding events. These cameras assisted in providing a clearer knowledge of when the individual returned to the enclosure with a timestamp or when it passed through the area, to establish if it relied on it as a food source.

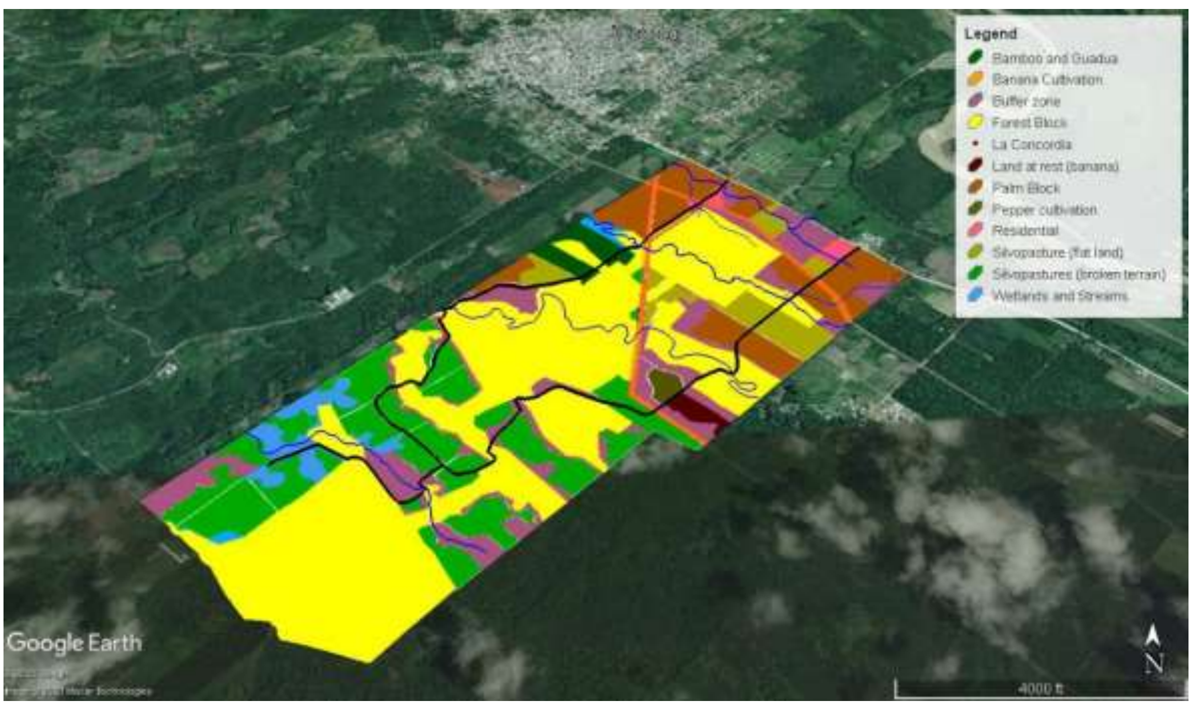

Figure 1: The map above shows how the protected forest, La Perla is divided into (flat land, bamboo, cultivation areas, etc.) (Credit: Jason Crespo)

Figure 2: The image shows the pre-release enclosure inside the release site, La Perla.

Figure 3: Image above shows the platform and design of interior of pre-release enclosure

Post-release monitoring equipment

Using GPS collaring technology can be complicated in jaguarundis because of their morphology- small size, lightweight body and small-narrow head. As a general rule, collars are not to surpass 3% of the animals' body weight in order to not interfere with daily activity and movements (Coughlin & Van Heezik, 2014). Considering the jaguarundi weighed 4.48 kg at the time of release, an appropriate collar could not exceed 134 grams. The team members researched a powerful enough collar for a species of a small size and a 122-gram collar was specifically ordered (Telonics, Tucson, AZ). To our knowledge, this is the first time GPS technology has been used on this species in this area.

The GPS collar was set to transmit locations once every four hours (1 am, 7am, 11am, 5pm). If the collar could not connect to the satellite due to canopy or cloud interference, the data stored on the collar. The collar included and accelerometer sensor that was configured to record movement per second in five-minute groups. The mortality sign was programmed to send a signal if after 10 hours there was no movement from the collar. An activity count could be transmitted if the animal changes position by lying on its side to lying on its chest, or if there is scratching by the collar. Data was sent and stored in full resolution and was received and managed using the program Telonics Data Converter Program (Telonics®, Tucson, AZ) (GEN4 GPS Systems Manual, 2019). Initially, the jaguarundi was fitted with the collar on January 14th, 2020 during a medical check-up in Tueri Animal Hospital (Fig. 4). Although, it had to be removed, relinked to the satellites, and refitted to the individual in working conditions before definite release as the metal enclosure and canopy cover blocked the GPS signal during the soft-release process. Before the individual was release, the collar was tested and successfully connected to the satellites (Fig.5).

Time transformations and adjustments were made to the final data set, converting the data from UTC to local time (GTM-5).

There was also a VHF beacon on the collar to monitor the jaguarundi from the ground and locate her when necessary. It was programmed to notify the following situations: collar approach within a 200-300 m range, collar's low battery, and unsuccessful tracking.

Figure 4: The image shows the jaguarundi during the medical visit in Tueri Animal Hospital, Quito and to put the collar before the release.

Figure 5: The image shows the testing for the collar to assure adequate signal strength and GPS point emission.

RESULTS

Pre-lease Activity and Monitoring

Male and female ocelots, along with other animals, wandered around the prerelease enclosure often. Although videos showed the jaguarundi clearly agitated by an ocelot's stalking behavior, camera trap photos showed that the jaguarundi frequently concealed itself in the box platform (Fig.6). These events took place during the night.

Although the GPS function of the collar was interrupted by the metallic enclosure, activity count was functioning. Activity count is measured during a 5-minute period (300 seconds). The pre-release data shows a bimodal activity pattern, peaks from early morning (06h00 - 10h00) with an average activity count of 164/300, and late afternoon (13h00 - 15h00) with an average activity count of 182/300. Decreases in activity between these peaks are observed around noon (12h00) with an average activity count of 156/300, and from early evening (18h00) with an average of 74/300. Around (1900), activity dramatically decreases and stays low for the night, an average of 6/300. Average activity during enclosure was 92/300 (Fig. 7).

Figure 6: Image shows inside the prerelease enclosure: At night, an ocelot is seen outside of the enclosure while the jaguarundi is concealed by her trap door.

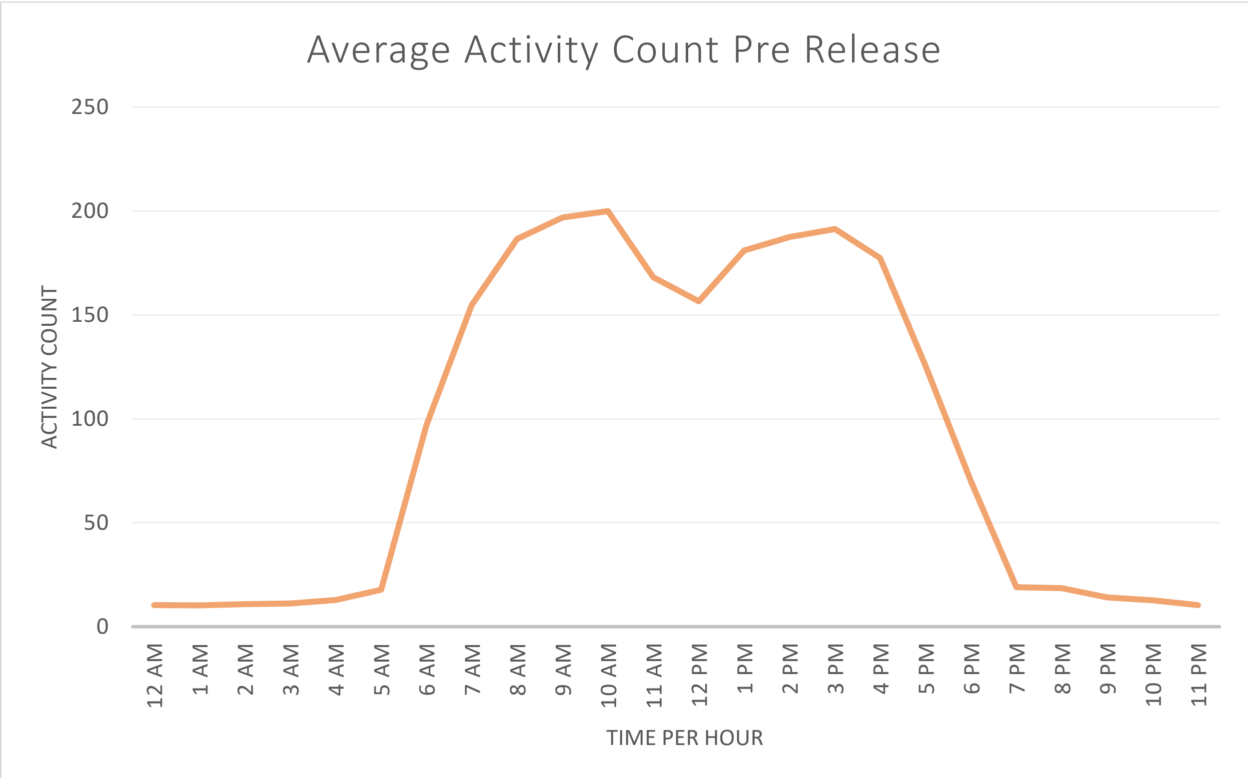

Figure 7: This figure shows the jaguarundis activity count while during the pre-release enclosure. Here we can observe the two peaks during the daytime followed by a low activity count for the entire night.

Release from Enclosure

The camera trap data showed the jaguarundi returned to the enclosure after the soft-release and returned a total of six times.

The jaguarundi was released in the reserve on April 15th, 2020, after spending 87 days in the prerelease enclosure. The enclosure was opened at 06h00 and it was confirmed that by 09h00 the jaguarundi had left the enclosure. Movement information, in comparison with the map with the GPS data, shows the jaguarundi traveled around the area for the first twenty-hour hour period as the felid is active during the daytime (09h00 - 17h00) (Appendix; Fig. 11,12).

Post-release Monitoring

Activity periods

The animal continued to show a bimodal active pattern spiking an activity count from early morning (06h00 - 08h00) with an average activity count of 111/300, and then steadily decreasing until late afternoon before its second peak (13h00 - 15h00) with an average activity count of 92/300. A stable decrease in activity is observed for the evening into the night with a low average activity count of 12/300 (Fig. 8). It is important to note that there is some activity in the late evening (2100), collar transmits activity count if the animal were to adjust its position or scratch by the collar. Oppositely to enclosure findings, overall average activity decreased, during the enclosure the average was 92/300, while outside the average was 53/300. Otherwise, the data were consistent with the activity displayed in the prerelease enclosure.

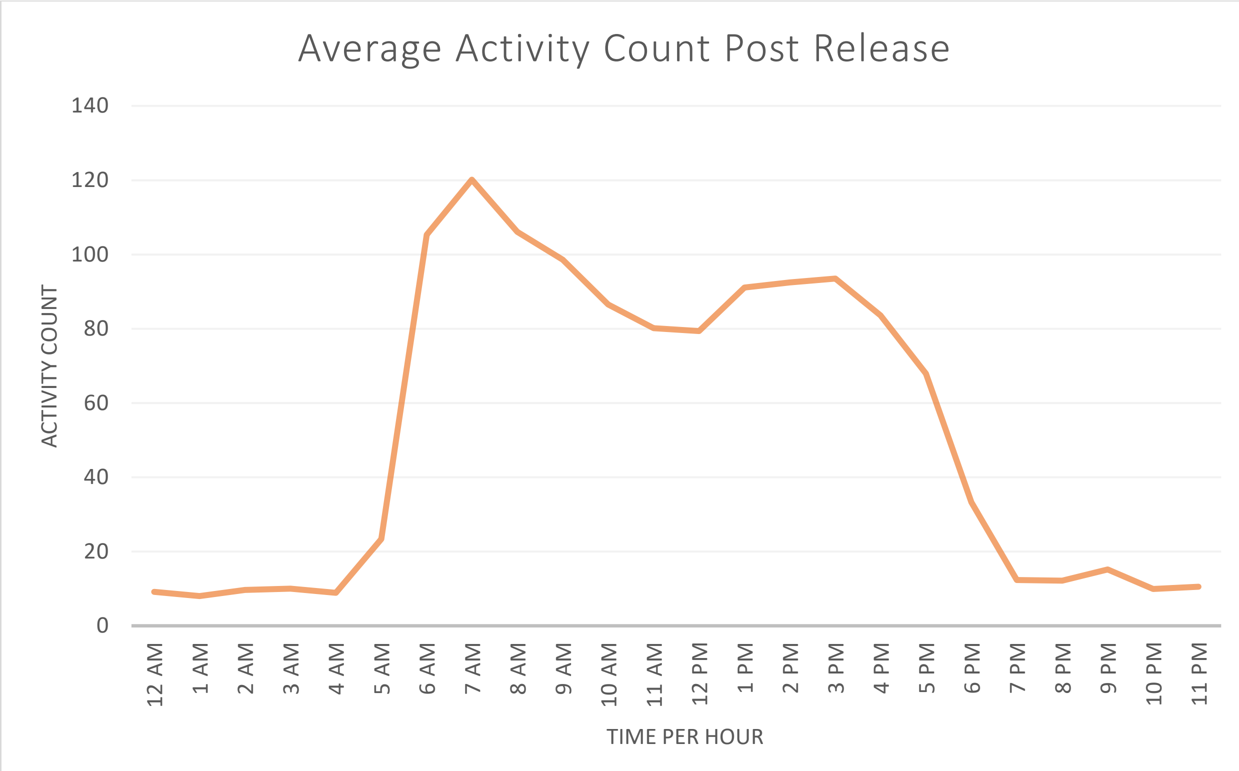

Figure 8: This figure shows the jaguarundis activity count after the release. We can see the two peaks during the daytime, like in the pre-release enclosure, followed by some activity for the night.

Movements

GPS locations from the collar show the jaguarundi spent most of its time inside the protected forest, in buffer zones and palm blocks; while outside of the perimeter by the cultivation station INIAP and monoculture areas in the southwest. It spent six days in agricultural zones at two different times. May 10-16, 1 km south the perimeter, circling within a radius of 281 m, and the next June 1-6, 2.2 km south of the perimeter, 1 km further south than earlier stay, circling this area in a larger radius of 844 m. This area is less than 100m from the road Ruta Plan Piloto. Although there is no permanent human settlement in the area, viewing from Google Maps, it appears to show it has been cultivated. On June 7th, the individual traveled back up north until a mortality signal was sent on June 9th at (1854). The full post-release data set was then retrieved from the collar.

Paths are calculated as straight lines across from one point to the next as the minimum distance traveled. Given that GPS emission were only sent four times a day, traveled distance times may be less than stated in all travels. The jaguarundi made three trips totaling approximately six hours to cross at least 2.3 km. The mean distance for the longer-than-1km-travels is 1.36km where it occurred almost every other day from 1100-1700. Whereas the shorter average distance is close to 166m for the same time period since it is the times emitted for GPS locations. Mean daily movements were of 1.2 km.

The jaguarundi returned to the release site six times with a distance of close to 130m, the last time being the end of May. Only two of those times the jaguarundi came to the enclosure and was captured by the camera traps (Fig. 9). The individual spent most days near canals, cultivation plantations and agricultural zones, buffer zones and by the south perimeter near the INIAP station (Appendix; Figure 12, 13, 14) This station is closely linked to the development of African palm cultivation in Ecuador but has no residential living on the property. Land use outside of the protected forest was not mapped and is largely unknown although broad speculations can be made using satellite imagery.

Figure 9: After the definite release, the jaguarundi returns to the enclosure on April 25th, 2020 at 1100AM and the camera trap was able to capture a picture.

Mortality Signal

Although mortality signal was emitted on June 9th, using the activity data from the collar, we deduct that the death occurred on the end of the night of June 7th when the activity count shows a dramatic decrease of activity and eventually to 0 for a sustained period of time (Fig.10). A few low counts were registered on June 8th which could be related to the movement of the body by the predator, a scavenger, or error in the dataset. Differences in frequency is common, standard error, a different activity count could be transmitted if the animal changes position by lying on its chest to lying on its side. The jaguarundi's remains were found using the last GPS location and the VHF. Only the skull, small fragments of the hide, and the collar were found at the entrance to a large burrow in a patch of secondary private forest. The owner had recently cleared the brush in this area, so despite placing camera traps near the burrow, no animal returned.

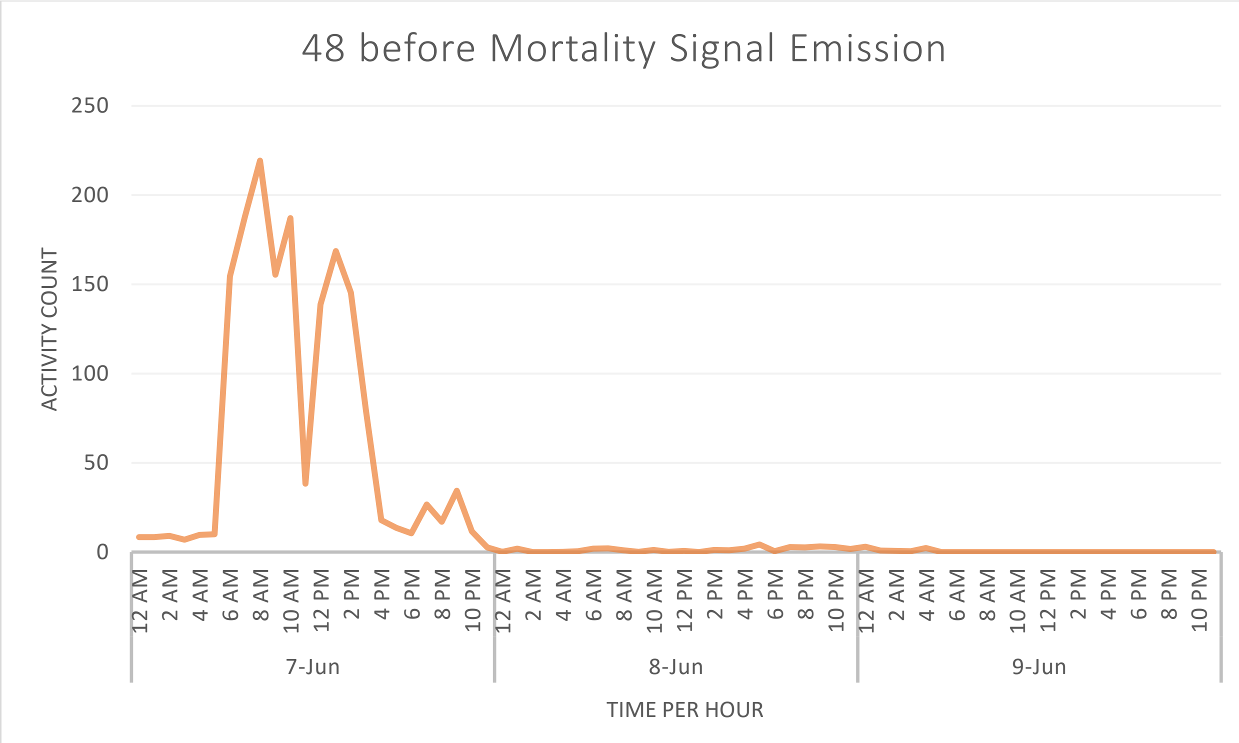

Figure 10: The figure shows the 48 hours prior to the mortality signal emitted on June 9th, 2020. The peaks during the day are higher than the average and the evening shows some activity before a presumed death in the late night.

DISCUSSION

In the 87-day soft-release enclosure the jaguarundi was healthy, independent, and competent. It seemed agitated by the interactions with male and female ocelots around enclosure. This demonstrates that the animal was able to display adequate interspecific interactions, as wild jaguarundis usually tend to hide and avoid ocelots. It has been demonstrated that population densities of smaller cats (e.g. jaguarundi, margay) tend to be reduced in areas where ocelots are present, in what is known as the Ocelot Effect (Caso & Oliveira, 2015; Cruz et al., 2018; Giordano, 2016; Kasper et al., 2016). Moreover, jaguarundis and ocelots display different temporal habits even though their home ranges overlap (Caso & Oliveira, 2015; Espinosa et al., 2018; Pérez-Irineo, Santos-Moreno & Hernández-Sánchez, 2017; Woolf et al., 2003). Jaguarundis are active during day hours as reported in previous studies and at La Perla, while ocelots are most active at night (Giordano, 2016; Pérez-Irineo, Santos-Moreno & Hernández-Sánchez, 2017).

Soft-release monitoring also showed bimodal, diurnal activity in concordance with the existing knowledge about the species habits (Caso, 2013; Giordano, 2016). The recorded daily activity exhibited two peaks separated by a steady decrease, which may be synchronized with the feeding schedule implemented by the facility where the animal was kept. The synchronization of captive-raised felids activity with feeding time has been described for related species to the jaguarundi, including puma (*Puma concolor*) and ocelot (*Leopardus pardalis*) (Adania et al., 2017; Lyons, Young, & Deag, 1997; Weller & Bennett, 2001). Wild jaguarundis also present this bimodal activity pattern with similar hour ranges to the ones reported here, appearing to be active during all daylight hours (Caso, 2013; Foster et al., 2009; Giordano, 2016). Therefore, the rehabilitated individual seemingly displayed this wild behavior characteristic during both pre-release confinement and post-release in La Perla.

Once the jaguarundi was released, it presented some night activity in the wild, while almost no night activity was observed during enclosure. Nocturnal activity might have reflected the individual's responses to noises or its repositioning at night as these movements are counted by the collar's monitoring system (GEN4 GPS Systems Manual, 2019). Similar results were obtained during a soft-release of a puma in Brazil (Adania et al., 2017). In comparison with enclosure time, an overall decrease in average daily activity count was observed in the months after definite release. These changes in activity count might be due to different energy investments. The individual was seen playing, jumping, and climbing (Appendix Fig.16) repeatedly during enclosure, similarly to other felids in captivity (Acaralp-Rehnberg et al., 2020; Houser et al., 2011). Playing behavior might have reduced in the wild, when hunting and hiding in refugia possibly became top-priority activities (Acaralp-Rehnberg et al., 2020).

The initial registered post-release routes could have been exploratory movements (Davis, 1983). The felid appears to move away from the enclosure site as it covered a 1-km distance after the first 48 hours post-release, seemingly wandering around the perimeter of release site La Perla, the reserve. The largest travelled distance registered was 2.4 km on May 9 (24 days post-release). This supports the theory that after a soft-release, animals do not cover great daily movements during the first day and night in the wild but instead, do it progressively (De Milliano et al., 2016). The mean daily movements of the individual were of 1.2 km, matching other reports where wild female jaguarundis travel up to 2 km in their daily movements (Caso, 2013; Foster et al., 2009 Kasper et al., 2016; Michalski, Crawshaw, De Oliveira, & Fabián, 2006). These wandering and exploratory spatial movements shown are analogous to those exhibited by relocated martens (*Martes americana*) (Davis, 1983), suggesting that the jaguarundi assumed a transient activity as it did not stay within an area for longer than 3 consecutive days while inside the La Perla. Transient individuals have been observed before and their occurrences is explained through hunting strategies or in avoidance of intra- or interspecific competitors (Caso, 2013; Foster et al., 2009). We also observed that the jaguarundi kept moving away from the release site, only returning twice within a 100 m radius near the enclosure. It did not return to the enclosure for supplemental feeding event though there was food placed there. This indicates that the individual was independent and competent to hunt, kill, and survive by itself.

La Perla was identified as a suitable release site for the individual due its mosaic landcover and ecologic features (e.g. altitude, climate) that support jaguarundi populations. The presence of wild-born jaguarundis and ocelots has been confirmed there (Bosque La Perla, 2020; Coronado Quibrera et al., 2019; Cruz et al., 2019; Espinosa et al., 2018; Stadtmann & Seddon, 2018). The jaguarundi seemed to frequent more agricultural areas (palm stations and monocultures), grasslands, and human-disturbed areas than primary forests, matching previous reports of the species' use of human-disturbed environments (Caso, 2013; Coronado Quibrera et al., 2019; Cruz et al., 2019; Espinosa et al., 2018). It was seen in maps that it spent more consecutive days, four to six, in monocultures areas. While in the protected forest, it spent no more than 48 hours in one specific location. A possible explanation of this pattern may be prey availability. Small felids feed mostly on small mammals, that are more abundant in the surroundings of human settlements, crops, or pastures (Caso, 2013; Foster et al., 2009). Jaguarundi occurrences in cultivations may be related with less inter-specific competitors due to the open spaces in these areas that are avoided by other cats, such as pumas, jaguars, and ocelots (Coronado Quibrera et al., 2019). Ocelot Effect might explain that jaguarundis are seen in human-disturbed areas to avoid ocelots that inhabit less disturbed habitats such as primary forests (Caso, 2013; Caso & Oliveira, 2015; Cruz et al., 2018; Espinosa et al., 2018; Giordano, 2016; Kasper et al., 2016).

Given the data, we hypothesize that the monitoring of the release process was successful in determining that the jaguarundi's behavior as a reintroduced individual. The jaguarundi exhibited similar ecological and behavioral patterns to its wild counterparts during pre- and soft-release procedures. We found that soft releases offer acclimation periods, in which the animal has the opportunity to familiarize itself with its new surroundings, while human interactions are reduced. The jaguarundi showed independence from humans by not returning to its enclosure for food and maintaining physical appearance on its own. During pre-release, the felid displayed competent hunting skills, a tendency to shy away from humans, but acted aggressive if people came near (Appendix; Fig. 17), and an ability to conceal itself during interspecific confrontations (e.g. ocelot) (see Fig.7), supporting the theory that its wild behavior was still present. The common thought that captivity induces animals to associate humans with rewards and positive scenarios has already been refuted as human contact does not intervene with basic feeding and care learning (Bauer, 2005). The premise that animals probably learn less about people in captivity than in freedom is becoming more accepted in behavioral biology (Bauer, 2005). This demonstrates that it is possible to reintroduce captive-raised jaguarundis into their native habitats, as other felid reintroductions have been considered successful under analogous circumstances (Adania et al., 2017).

However, 55 days after release the activity declined abruptly between June 7th and June 8th likely due to an injure causing the death of the jaguarundi, which seems to have occurred in the late evening of June 7th. The slight activity registered the day after that could have been caused due to another animal moving the carcass. We believe this also might have influenced the late emission of the mortality sign on June 9th as the notification is configured to send only when activity count is zero for 10 hours (GEN4 GPS Systems Manual, 2019).

The cause of death is still unknown. The only information available is that the skull (Appendix; Fig. 18) and collar were found near a burrow. Based on this, we discuss some possibilities below. Inter-specific competitors, like tayras (*Eira barbara*), are among the main threats to the jaguarundi (Caso & Oliveira, 2015; Giordano, 2016). Tayras are small, fierce mammals, whose activity pattern and home range greatly overlap with the jaguarundi (Foster et al., 2009; Giordano, 2016; Michalski et al., 2006). Both species appear to be competitors as they prefer the same prey, sharing 40% of dietary components (Foster et al., 2009). As a consequence, jaguarundis and tayras are sighted in human-disturbed areas, where their preferred prey inhabits (Foster et al., 2009; Michalski et al., 2006). These factors explain that tayras might exhibit aggressive traits toward jaguarundis, including in hunting. Studies have revealed that reintroduced captive carnivores are susceptible to unsuccessful competitor avoidance, supporting a hypothesis that a tayra could have injured or killed the released jaguarundi (Jule, Leaver & Lea, 2008). Tayras are efficient hunters, hunting from trees due to their excellent climbing abilities, and on the ground. They exhibit group hunting for larger prey like monkeys (*Callithrix* sp.), howlers (*Alouatta palliata*) and newborn sloths (*Bradypus tridactylus*) (Asensio & Gómez-Marín, 2002; Bezerra, Barnett, Souto, & Jones, 2009; Camargo & Ferrari, 2007; Mohammed, 2011). Evidence that points to this hypothesis is that the animal's skull was found near a burrow, which is a typical hunting feature of tayras (Mohammed, 2011). Furthermore, the burrow was located 3.3 km outside of La Perla (Fig 19), in a mosaic of fragmented secondary forest that both species prefer (Foster et al., 2009; Michalski et al., 2006). It is also possible that a tayra found the jaguarundi carcass, proceeded to consume the body and then moved the skull to a burrow (Smith, 2000). Unfortunately, this information cannot be confirmed as the area has recently been cleared and there is no information of the animals that resided there.

Ocelots are other competitors that might have caused the jaguarundi's death. Ocelots hunting is characterized by stalk and pounce with a killing bite, followed by skinning, consumption and cover of the remains of their prey at the kill site (Bianchi, Mendes, & de Marco Júnior, 2010; Geerah, 2011; Murray & Gardner, 1997). Thus, if the jaguarundi would have fallen prey to an ocelot the skin would have been found at the recovery place, and the skull might have displayed bite marks to indicate a felid attack (Bianchi et al., 2010; Geerah, 2011; Murray & Gardner, 1997). In spite of the fact, ocelot hunting prey that weigh more than 2 kg is relatively infrequent (Murray & Gardner, 1997). Even considering these factors, we still cannot know for sure as there are other possible explanations.

Another plausible alternative explanation of the death of the released jaguarundi is human-wildlife conflict. It was evidenced that the felid spent most of its time in human-disturbed areas, specifically in agricultural zones, including palm stations and monocultures. Jaguarundis are often killed in these spaces as pre-emptive or retaliatory persecution for feeding on poultry or because they are perceived as a threat to human and livestock welfare (Caso & Oliveira, 2015). The individual was seen three times near temporary residential settlements, although there is no evidence that it killed any livestock. This is concerning because even when small felids can be successfully reintroduced into the wild, they still face the threat of human–wildlife conflict (Houser et al., 2011). The same pattern has already been documented for reintroduced cheetahs and pumas (Adania et al., 2017; Houser et al., 2011). In fact, it has been determined that humans were the direct cause of death in over 50% of all captive-bred release fatalities (Jule, Leaver & Lea, 2008). For instance, it has been demonstrated that free ranging dogs present near residential areas and agricultural landscapes exert deleterious effects on the wildlife inhabiting landcover mosaics. These negatively impact wildlife that also show diurnal activity, as the jaguarundi, and can disturb the spatial distribution of other sympatric carnivore species (Carvalho et al., 2019). As such, we suggest that when possible, reintroduced felids be released in areas far from human activities as this can aid in lowering human-wildlife conflict, in addition to dogs that are frequently accompany owners of livestock. Although any of these suggested scenarios could have been the cause of death for the released jaguarundis, the real cause remains unknown.

We suggest for future jaguarundi reintroduction programs that soft-release methods be implemented as they allow the display of progressive development of wild behavioral traits (Adania et al., 2017; Davis, 1983; Eastridge & Clark, 2001). Given that the animal appeared to be transient as it did not stay within an area for longer than 3 consecutive days, we recommend researching soft-release methods to aid in the establishment of sedentary movements that are those carried out within a specific area (Davis, 1983). For example, releasing several individuals together with an equal sex proportion (Davis, 1983; Eastridge & Clark, 2001). We urge the use of post-release monitoring to assess reintroduction success, because most reintroduction efforts lack proper monitoring systems (Houser et al., 2011; Thorne et al., 1996). It is highly recommended to include community education before, during and after release projects of carnivores to minimize and address human-wildlife conflict and to build a corridor of tolerance between humans and animals because this constitutes a main threat to reintroduced carnivorous survival (Loveridge et al., 2010; Thorne et al., 1996). The literature shows that the most significant characteristics of successful reintroduction projects are acclimatization, monitoring, local employment, and community education (Thorne et al., 1996). In fact, 100% of successful animal releases documented have incorporated community education. Principal goals of community education must be the reconciliation of the expansion of the agricultural frontier with the conservation of felids, including large and small cat species, and other wild, native species (Boron et al., 2020). A community outreach and education program should also have a component that allows local people to contact the project manager to remove and relocate the released animal if any conflicts occur, instead of immediate killing. Also, a good education strategy could be highlighting the important ecological roles that carnivores and felids occupy as top predators and the resulting benefits to humans. Incorporating these steps could be key for future successful reintroductions.

CONCLUSIONS

Although captive raised, this individual showed activity periods that match those recorded in wild individuals, both pre- and post-release. Moreover, the jaguarundi was able to hunt and feed itself for an extended period of time after it was released. It also remained at a consistent activity level throughout her release until a drastic and abrupt change hours before it reported a mortality signal, indicating an attack. This individual has shown it is adaptable to moderate anthropogenic disturbances like human-modified landscapes and frequented agricultural stations (INIAP) and monoculture areas. The GPS data indicates the jaguarundi appeared to prefer agriculture zones, including palm stations and monoculture, over thick primary forest habitat that the protected forest provided. This could be due avoidance of sympatric carnivores in the dense forest of La Perla or an easier hunting ground provided by the more open agricultural areas, a behavior that has also been reported for wild individuals. Nonetheless, this individual appeared to be successful until 55 days after the release, when the mortality signal was received. The cause of death is still unknown, hence we suggest that inter-specific competitors, such as tayras, ocelots or free ranging dogs, or human-wildlife conflict be a plausible explanation for its this. This is concerning due to human-modified locations in mosaics of tropical forest will soon be more common near protected areas and more species will have to face these shifting borders and changing landscapes. As such, it will be crucial to include monitoring programs, community education, and local involvement in future jaguarundi reintroduction programs.

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APPENDIX: FIGURES

Figure 11: Figure shows the first 24 hours after the release. This activity count shows similarities with the behavior while inside the pre-release enclosure.

Figure 12: The image shows the GPS points emitted during the first 24-hour post release, showing movement in circular motion around the release area.

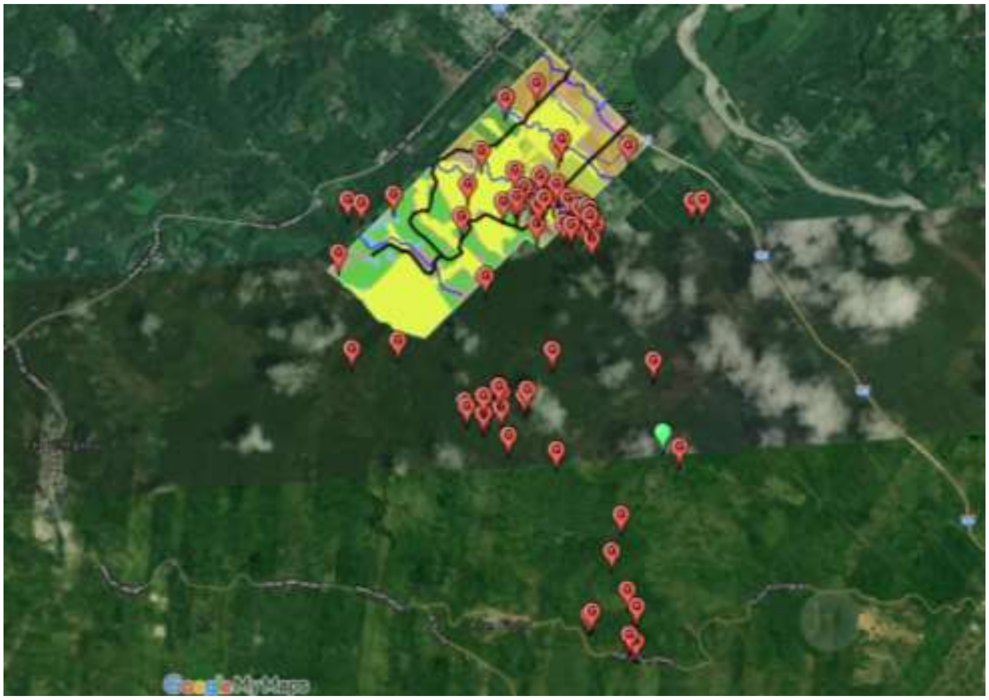

Figure13: The figure above shows the gps points that the collar data stored. Each point has a description of date and time and was used to determine path and distance.

Figure14: The image above shows the GPS points of the six-day stay of the jaguarundi. The jaguarundi also stayed 1km further south, in a similar agricultural area for also six days.

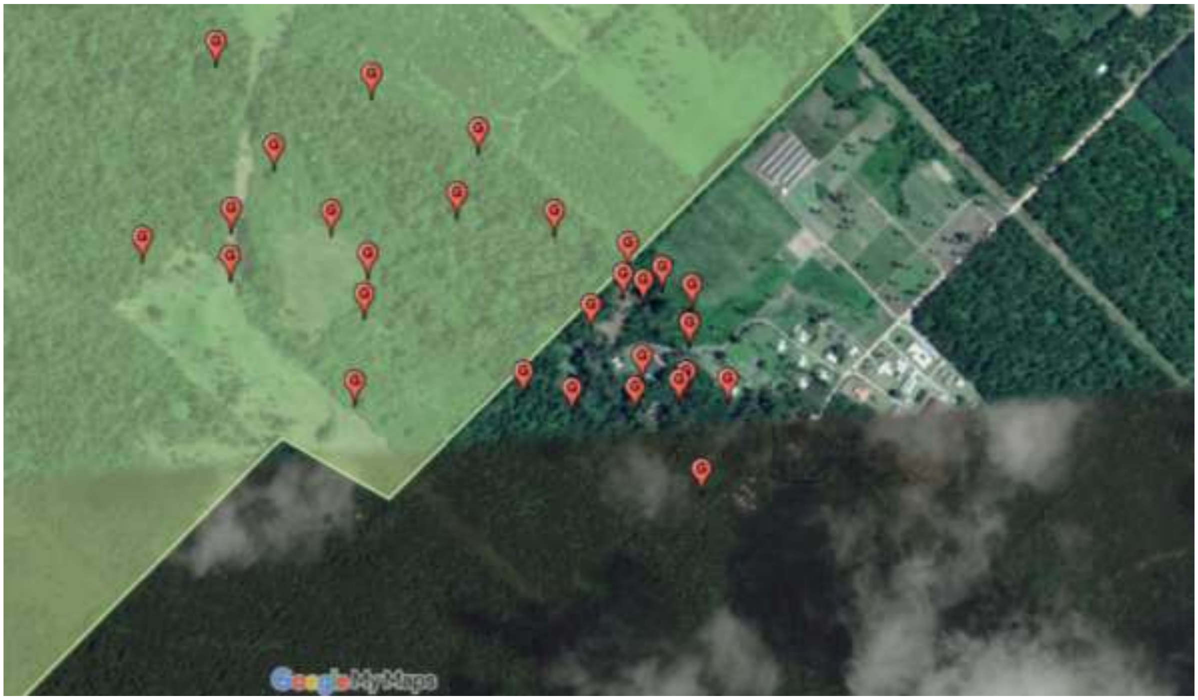

Figure 15: The image above shows the GPS points of the four-day stay and frequent visits to the INIAP station on the south perimeter of the protected forest, La Perla

Figure 16: While inside the pre-release enclosure, the jaguarundi can be seen climbing and practicing her abilities.

Figure 17: The jaguarundi is captured above being showing aggressive traits towards humans when placed into the pre-release enclosure.

Figure 18: The picture is the skull of the jaguarundi that was found outside of the protected forest, La Perla.

Figure 19: Image of map shows distance (3.3km) south of perimeter of where the skull of the jaguarundi was recovered.

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