ARTICLE

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Identifying individual ocelots by coat patterns using the Whiskerbook

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Resumen

La identificación de animales a nivel individual es clave para estudios de abundancia, densidad y parámetros de dinámica poblacional de la vida silvestre, como reproducción y supervivencia. Wildbook es una base de datos gratuita y online que se emplea para identificar una amplia gama de especies a nivel individual comparando sus marcas individuales en fotografías, proporcionadas ya sea por esfuerzos de ciencia ciudadana o por monitoreo pasivo. Aquí presentamos el primer registro del uso de la plataforma Whiskerbook para identificar especies manchadas en América del Sur. Los datos fueron obtenidos en el monitoreo por cámaras trampa durante 5 años en la Estación Ecológica Terra do Meio en Brasil, con en media 60 cámaras instaladas por año y un total de 20.668 días de registros fotográficos. Tuvimos identificaciones de al menos 78 ocelotes a lo largo de los cinco años de monitoreo, de un total de 810 registros de cámaras trampa. Las recapturas se registraron a partir de cuatro años y siempre ocurrieron dentro del año siguiente a la primera captura. También se registraron recapturas dentro del mismo año y lugar para 17 individuos de ocelote y las co-ocurrencias sugirieron que se registró un promedio de 3,7 individuos compartiendo 14 cámaras a lo largo de los años. A pesar de las limitaciones, Whiskerbook ha demostrado ser una gran herramienta para cuestiones de conservación, y su potencial debería ser explorado más a fondo por investigadores de vida silvestre.

Palabras clave: Whiskerbook, patrón de manchas, individuo, identificación, población.

Abstract

The identification of animals at an individual-level is the key for studies of wildlife abundance, density, and population dynamics parameters, such as reproduction and survival. The Wildbook is an online and free database employed to identify a wide range of species at the individual-level by comparing their individual marks in photographs, provided either by citizen science endeavors or passive monitoring. Here, we present the first record of the use of the Whiskerbook platform to identify spotted species in South America. The data was obtained by the camera trap monitoring performed at the Ecological Station Terra do Meio in Brazil throughout five years, with an average of 60 cameras/year

and a total of 20.668 days of records. We identified at least 78 ocelots along the five years of monitoring, from a total of 810 camera trap records. Recaptures were recorded from four years and occurred always within one year from the first capture. Recaptures were also recorded within the same year and place for 17 ocelot individuals and co-occurrences suggested that a mean of 3.7 individuals were recorded sharing 14 cameras over the years. Despite Whiskerbook's limitations, it has demonstrated to be a promising tool for conservation issues, and its potential should be further explored by wildlife researchers.

Key words: Whiskerbook, spot patterns, individual, identification, population.

1. INTRODUCTION

The identification of animals at an individual-level is key for assessments of wildlife abundance, density, movement patterns, and population dynamics parameters, such as reproduction and survival (Sollmann *et al.,* 2011; Rovero *et al*., 2014; Lorm *et al.,* 2023). Similarly to human fingerprints, many animals have unique pattern marks that can be used to differentiate one individual from another (Petso *et al.,* 2021). Natural individual marks can be found in a wide range of taxa, from fish to mammal species (Araujo *et al*., 2022; Burgstaller *et al.,* 2021; Nepovinnykh *et al.,* 2022), and can be in all shapes and formats as stripes, fin edges, spots, coat and whisker patterns (Osterrieder *et al.,* 2015; Camarena-Ibarrola *et al.,* 2019; Petso *et al.,* 2021).

The Wildbook is an online and free database employed to identify a wide range of species at the individual-level, by comparing their individual marks in photographs, provided either by citizen science endeavors and passive monitoring (e.g. camera traps) (Berger-Wolf *et al.,* 2017). Besides the Whiskerbook platform (http://www.Whiskerbook.org), which aims to identify spotted species (jaguars, ocelots, clouded leopards, snow leopards, etc.), the Wildbook comprises other eight platforms intended to identify other mammalian groups: the Flukebook (whales and dolphins); GiraffeSpotter; Zebra Codex; Wildbook for Lynx (iberian lynxes); African Carnivore Wildbook (wild dogs, cheetahs, brown and spotted hyenas and leopards); Wild North Wildbook (cougars, bobcats, Canada lynxes and western spotted skunks); Seal Codex and Codex for Deer (Berger-Wolf *et al.,* 2017).

The ocelot *Leopardus pardalis* is a widespread felid species in the American continent, spanning from Texas to north-eastern Argentina (Paviolo *et al.,* 2015). The species is considered as 'Least Concern' by the IUCN Red List (Paviolo *et al.,* 2015), but is classified as 'Endangered', in the United States and Mexico; as 'Threatened' in some regions of Brazil and as 'Vulnerable' in Argentina and Colombia (US Fish and Wildlife Service, 2016; Alves *et al.,* 2019; Avilla-Villegas *et al.,* 2023). Proper assessments of its conservation status require better data on population size and trends throughout its distribution. Therefore, the present study aims to communicate the first use of the Whiskerbook (by Wild Me: wildme.org) to identify a spotted species in South America using camera trap images.

2. MATERIAL AND METHODS

2.1. Study Area

The study was performed at Terra do Meio Ecological Station in the state of Pará, North Brazil, a region which extends to 7.900.000 km² between the Iriri and Xingu rivers. The Station is formed of a mosaic of federal and state level protected areas and Indigenous lands, that makes it an extensive track of pristine Amazonian forests and immense cultural diversity. The landscape in the study region is dominated by upland forest, which is majorly intact and a tropical humid climate with marked dry and raining seasons (Schwartzman *et al.,* 2013; de Paula *et al.,* 2022) in the state of Pará within Brazilian Amazonia. Camera trap surveys were conducted between 2016 and 2023 as part of the Brazilian *in situ* monitoring program of Federal Protected Areas (Programa Monitora). Throughout the five years of monitoring, 146 permanent sampling sites were sampled at one or more years for a total of 350 camera deployments throughout the study (with an average of 60 deployments per year). Sampling sites were distributed in regular arrays with a density of one sampling site per 2 km² (Figure 1). Cameras were attached to trees at knee height, perpendicular to the ground and facing either north or south to avoid direct sunlight at sunrise and sunset, and the vegetation directly in front of cameras was cleared. Cameras were set to operate continuously for at least 30 days per year, following the Terrestrial Vertebrate Protocol from the Tropical Ecology, Assessment and Monitoring (TEAM Network, 2011). Images were processed in the Wildlife Insights platform (Ahumada *et al.*,2020).

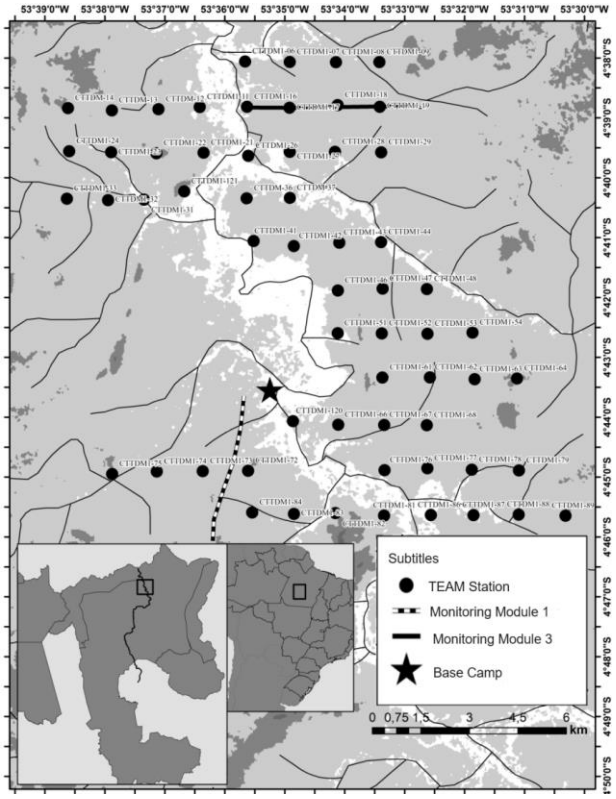

FIGURE 1. Terra do Meio Ecological Station in the state of Pará in North Brazil. Points represent each deployed camera trap position throughout the six years of monitoring.

2.2. Methodology

First, we selected the ocelot images from our dataset in which at least one distinguished angle (left/right/back/front) was visible and could have their pattern recognized by the

algorithm, thus discarding images in which the individual was too far away from the camera or blurred. The selected ocelot images were uploaded and stored in the global online Wildbook database for whiskered species, the 'Whiskerbook' (Berger-Wolf *et al.,* 2017). After all images were uploaded, we ran them through detection, a step in which the algorithm scans the images and detects the shape of the animal and its position (left, right, back, front) in each image. Then, as the final step, we began the identification of one file at a time, beginning with the ones from 2016 and following through the subsequent years of 2017, 2018, 2019, 2022 and 2023.

During the matching process, we chose to use the 'image scores' rather than 'individual scores' tool to improve the algorithm evaluation and thus generate better results among the match candidates. The artificial intelligence in Whiskerbook uses the HotSpotter algorithm - patterned species instance recognition - which analyzes the textures in an image to find recognizable patterning and then compares those against other images uploaded in the database (Crall *et al.,* 2013). Then, given the results, the user is responsible to either identify the individual as an already identified one, according to the matching options, or as a new individual. The confirmation of the match was done by using the 'inspect tool' which highlights the similarity between the target photograph (on the left) and the suggested possible matches in the database (on the right) (Figure 2).

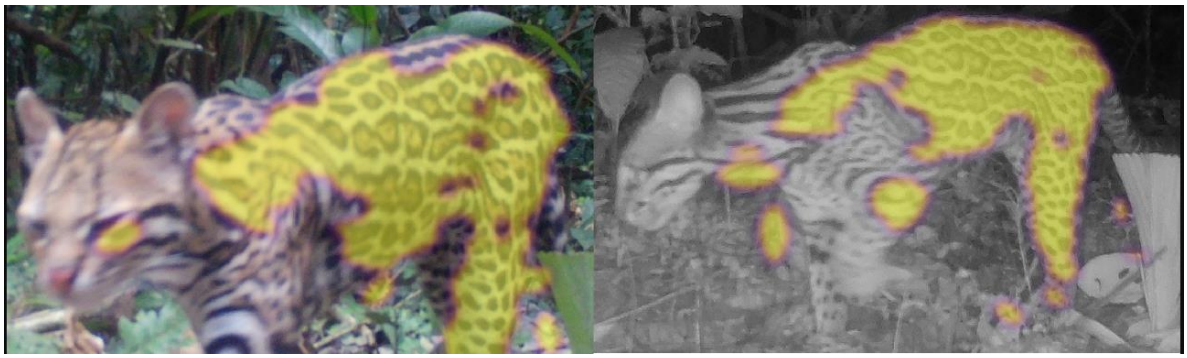

FIGURE 2. An individual of *Leopardus pardalis* identified using the inspect tool from the Whiskerbook platform. The animal was recorded at the same site on different days in 2018.

Given that ocelots have asymmetrical coat patterns, which means that the animal's left-side marks are different from those on the right-side, and that not all individuals cross the camera showing all their sides and angles, it is impossible to ensure that one individual might not have been identified more than once. Therefore, the minimum number of individuals in the area was estimated from the aggregated images for each flank separately.

3. RESULTS

From a total of 810 camera trap ocelot records, taken throughout 20.668 days of sampling effort and across the five years of monitoring, we obtained 164 individual identifications of ocelots, 65 of unidentified sex, 53 females and 46 males. 71 individuals were identified by the left side flank, 78 by the right side flank, seven in full (both sides), five by the back and one by the front. The Figure 3 plots the number of ocelots records and the amount of new identified individuals for each of the five years, respectively.

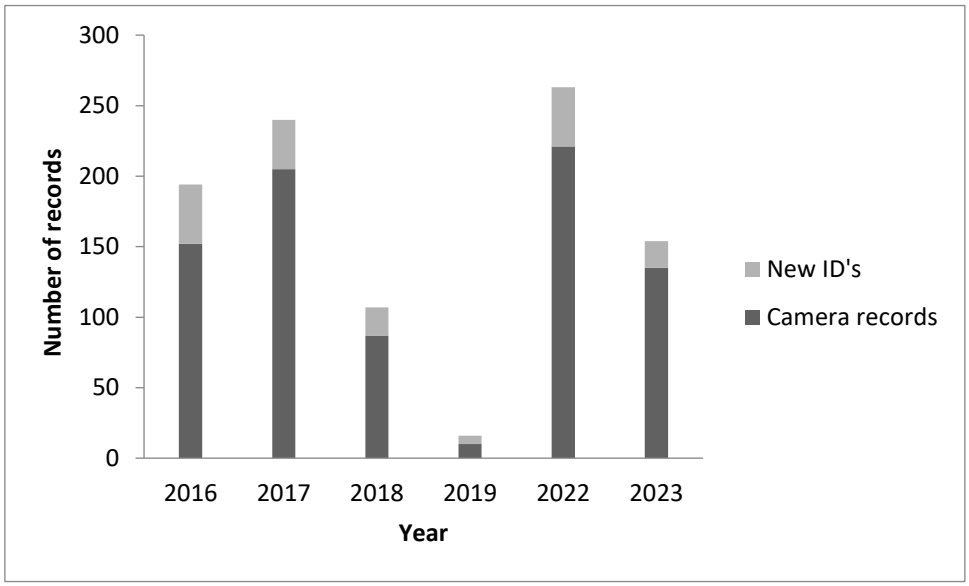

FIGURE 3. Number of records taken by camera traps in each year and the number of new identified individuals throughout the study.

The decrease in the number of new individuals from 2016 to 2018, and from 2022 to 2023 is due, mainly, to the recapture events recorded in 2017, 2018 and 2023.

Recaptures were recorded from all years except 2019 and happened always from one year to the next one. The longest interval between resights was 1.1 years for a male ocelot. The largest distance between resights was 3.92 km for a female. A total of 10 recaptures from one year to another were recorded throughout the five years of monitoring. From those events, five were from animals seen at the same site as the first capture and five at different sites (Figure 4).

FIGURE 4. A and B: Recapture of an identified ocelot by the same camera in 2017 and 2018. C and D: Recapture of an identified ocelot by different cameras in 2016 and 2017. The white box shape highlights the coat pattern marks used to confirm the match.

Recaptures were also recorded within the same year and place for 17 individuals, with an average recapture frequency of 2.3 times per individual per year, with the maximum frequency corresponding to six times in distinct hours and days. A female was recorded across five days by the same camera, with one of the captures being joined by a cub. A male individual was captured in two different places, covering 3.2 km in nine days in 2018. Regarding co-occurrences, a mean of 3.7 individuals were recorded sharing 14 cameras over the years (n=52). The few recaptures in different sites is probably due to the wide spacing between cameras, which may have led to no more than one camera per home range (Gonzalez-Borrajo *et al.*, 2017). This occurred because the methodology used on the sampling was designed for a wider goal other than ocelot population estimate, being part of a larger project that aimed to sample most of the medium- and large-size species in the Amazon biome.

4. DISCUSSION

Our dataset consisted of 810 images with varying levels of image quality, given mainly to the large range of light availability (e.g. Figure 4 C and D) and closeness of the individual to the camera. However, the Whiskerbook demonstrated to deal well with poorer quality images as long as the pattern remained distinguishable. As quality could be a data aspect difficult to control, as it can be influenced by environmental and physical factors, studies

aiming to improve individual identification, should consider trapping arrays with double-camera stations.

While many studies aiming to evaluate ocelot and other spotted species density and abundance are still relying on human visual inspection in the matching process (Wolff *et al.,* 2019; Medonça *et al.,* 2022; Stenberg *et al.,* 2023), recent studies have repeatedly demonstrated that this method has resulted in a systematic population overestimation. For instance (Johansson et al., 2020) noticed a misidentification rate of 12.5% in all 40 occasions presented to eight observers in a study with snow leopards; (Verschueren *et* al., 2023) observed an overestimation of 7% for cheetah and 22% for leopard populations when identified manually, compared to the results from the HotSpotter algorithm analysis; and (Bohnett *et al.,* 2023) indicated that observers using the Whiskerbook platform practiced significantly fewer misclassifications (e.g. splitting one individual into two different individuals) than the manual visual inspection, thus improving accuracy on abundance estimates. Notwithstanding, the visual inspection is also a time-consuming and exhaustive method, as it requires the researcher to look carefully at each photo, analyze it and check if that pattern has been seen before. In a personal communication, Mendonça reported to have taken 10 days to identify 15 individuals of jaguar (*Panthera onca*) (a mean of 1 individual/day), from 561 images using human visual inspection. As for the present study, we report that, using the Whiskerbook, it took 26 days for one person to identify all 164 ocelot individual identification going through 810 images (with an average of 6 individuals/day). This fact highlights the potential of the Whiskerbook as an identification tool for conservation purposes.

The HotSpotter program has been used in Central, North and South American studies to identify ocelots and jaguars (Nipko *et al.,* 2020; Lombardi *et al.,* 2022; Wiig *et al.,* 2023), and the Whiskerbook/Wildbook has been used for the Eurasian lynx (*Lynx lynx*) (Stopić, 2021), the snow leopard (*Panthera uncia*) (Bohnett *et al.,* 2023), cheetahs and leopards (Verschueren *et al.,* 2023). However, there is no recorded evidence of the Whiskerbook being previously used to identify spotted species in South America, which makes the present study the first to do so. This fact and empirical observations (do Val, HGP personal communication) reinforce how unequally widespread this tool is among researchers from different parts of the world, especially those from the South American continent and considering how biodiversity conservation in these regions could benefit from the use of this tool.

Besides the use for individual identification, the Whiskerbook platform also allows their users to store and share their images with other users and to upload ecological, behavioral, and biological data on each identified individual, such as sex, hierarchical position (especially for social species), and family bonds (e.g. mother, cub). Regarding exporting data, the platform produces a printable handbook with the images of the identified individuals, providing useful material to be taken to the field. Despite its performance, the Whiskerbook still holds some limitations, with the most relevant one related to data exportation. Although it is possible to download the data in capture history format, the platform does not produce a file comprising all identifications and their related coordinates. Therefore, this data needs to be compiled manually throughout the matching

process by the users. Nevertheless, the Whiskerbook has demonstrated to be a promising tool for conservation issues, and its potential should be further explored by wildlife researchers worldwide.

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