Digital photogrammetry applied to footprints of medium and large mammalfrom two forest fragments in the area influence of the Ilha Solteira Hydroelectric Complex, Brazil

Fotogrametria digital aplicada a pegadas de mamíferos médios e grandes de dois fragmentos de floresta na área de influência do Complexo Hidroeléctrico da Ilha Solteira, Brasil

DOI:10.34117/bjdv7n1-209

Recebimento dos originais: 10/12/2020
Aceitação para publicação: 10/01/2021

Juan Vítor Ruiz
Formação: Mestre em Biologia Animal
Instituição: Universidade Estadual Paulista, FEIS - Departamento de Biologia e Zootecnia.
Endereço: Passeio Monção, 226, Zona Norte. CEP: 15385000 - Ilha Solteira, SP – Brasil
E-mail: juanvitorruiz@gmail.com

Marcos Vinicius Lopes Queiroz
Formação: Bacharel em Ciências Biológicas
Instituição: Universidade Estadual Paulista, FEIS - Departamento de Biologia e Zootecnia.
Endereço: Passeio Monção, 226, Zona Norte. CEP: 15385000 - Ilha Solteira, SP – Brasil
E-mail: marcosv_queiroz@hotmail.com

Eleonore Zulnara Freire Setz
Formação: Professora Assistente Doutora
Instituição: Universidade Estadual de Campinas, Instituto de Biologia.
Endereço: Rua Monteiro Lobato 255 Cidade Universitária. CEP: 13083-862 - Campinas, SP – Brasil
E-mail: setz@unicamp.br

Felipe Chinaglia Montefeltro
Formação: Professor Assistente Doutor
Instituição: Universidade Estadual Paulista, FEIS - Departamento de Biologia e Zootecnia.
Endereço: Passeio Monção, 226, Zona Norte. CEP: 15385000 - Ilha Solteira, SP – Brasil
E-mail: fc.montefeltro@unesp.br

ABSTRACT

Medium and large neotropical mammals are usually nocturnal, shy animals, which challenge direct observations, and compromising the study these animals in the field. One solution to this problem is the analysis of vestiges, which include tracks and footprints, as a way to assess the community of medium and large terrestrial mammals. Species

identification can be based on the observation of key characters of footprints, which is commonly evaluated through comparisons with photographs and linear drawings in specialized guides. However, since the quality of each footprint depends on the environment factors, including substrate and climate conditions, the guides represent ideal footprints that do not necessarily reflect the conditions most common seen in the field. We carried out an inventory of medium and large mammals through footprint analysis in two fragments in the region under the influence of the Ilha Solteira HPP, Brazil, between February and April 2019. We recorded a total of 16 mammals, of seven orders. We rendered three-dimensional footprint models of four of the recorded species using digital photogrammetry. We argue that this technique allows the reconstruction of the footprints in a faithful way for medium and large neotropical mammals, posing as a viable, and inexpensive alternative to the two-dimensional images of field guides, with the advantage that the 3D models can be analysed from different angles and be produced from footprints on different substrates.

Keywords: Mammals, Footprints, Digital Photogrammetry, Research Methodology, Ilha Solteira, Forest Fragments.

RESUMO

Os mamíferos neotropicais médios e grandes são geralmente animais nocturnos, tímidos, que desafiam as observações directas, e comprometem o estudo destes animais no campo. Uma solução para este problema é a análise de vestígios, que incluem pegadas e pegadas, como forma de avaliar a comunidade de mamíferos terrestres de médio e grande porte. A identificação de espécies pode ser baseada na observação de personagens-chave de pegadas, que é normalmente avaliada através de comparações com fotografias e desenhos lineares em guias especializados. No entanto, como a qualidade de cada pegada depende dos factores ambientais, incluindo o substrato e as condições climáticas, os guias representam pegadas ideais que não reflectem necessariamente as condições mais comuns vistas no campo. Realizámos um inventário de mamíferos médios e grandes através da análise da pegada em dois fragmentos na região sob a influência da HPP Ilha Solteira, Brasil, entre Fevereiro e Abril de 2019. Registámos um total de 16 mamíferos, de sete ordens. Fizemos modelos de pegada tridimensionais de quatro das espécies registadas, utilizando fotogrametria digital. Argumentamos que esta técnica permite a reconstrução das pegadas de forma fiel para mamíferos neotropicais médios e grandes, fazendo-se passar por uma alternativa viável e barata às imagens bidimensionais dos guias de campo, com a vantagem de os modelos 3D poderem ser analisados de diferentes ângulos e serem produzidos a partir de pegadas em diferentes substratos.

Palavras-chave: Mamíferos, Footprints, Fotogrametria Digital, Metodologia de Investigação, Ilha Solteira, Fragmentos Florestais.

1 INTRODUCTION

Mammals play important roles in maintaining the environment, either through pollination, herbivory, seed dispersal or predation (STEVEN; PUTZ, 1984; DA FONSECA; ROBINSON, 1990; MOTTA-JUNIOR; MARTINS, 2002; KAGEYAMA; GANDARA, 2003; O'FARRIL et al., 2013). One of the largest threats to this group is the

environmental fragmentation. This action leads to restrictions on the area of occurrence and immigration, limiting or preventing gene flow with nearby populations. Ultimately, these processes lead to local extinctions, such as tapirs, coatis, peccaries and deer (TURNER; CORLETT, 1996; MIOTTO et al., 2012). The removal of these mammals from an area can cause major impacts, severely interfering with the local ecosystem. In addition, fragmentation is often accompanied by the establishment of roads, which increases the mortality rate of native mammals by road kills and facilitates the access of hunters and domestic species, such as dogs, cats and cattle, who acts as potential competitors and vectors of diseases (TROMBULAK; FRISSELL, 2000; MAGIOLI et al. 2019).

Knowing the diversity of medium and large mammals in fragmented areas is extremely important to understand what steps can be taken to avoid local extinctions. Surveys and track analysis are one of the most efficient methods for sampling medium and large mammals, given the difficulty of direct observation of these predominantly nocturnal and shy animals (MUNARI, 2008). Therefore, proper identification of tracks is indispensable for these studies. Typically, the identification and comparison of mammal footprints is done based on identification guides containing drawings and photographs, as well as collections of footprints in plaster endocasts. (BECKER; DALPONTE, 1991; BORGES; TOMAS, 2001; MORO-RIOS et al., 2008).

Digital photogrammetry is a technique that enables the development of three-dimensional digital models based on photographs. The use of this technique is already established in other areas of biology, as in the study of fossil footprints (KLEIN et al., 2015; LALLENSACK et al., 2015). To date, however, this tool has not been extensively applied to studies of footprints of living mammals.

The present study identified tracks of two medium and large mammal communities in forest fragments in areas of influence of the Ilha Solteira Hydroelectric Complex in São Paulo, Brazil. From the results of the surveys, the use of photogrammetry was applied for the construction of digital footprints models of four of the recorded mammal species, aiming to evaluate the potential for use of these digital models in the field.

2 MATERIAL AND METHODS

2.1 SURVEY OF MEDIUM AND LARGE MASTOFAUNA

Tracks surveys were carried out in two 1,500-meter transects on dirt roads located in forest fragment areas in the area of influence of the Ilha Solteira Hydroelectric Complex, in São Paulo State and Mato Grosso do Sul State, Brazil (fig. 1). One of the transects was located at Fazenda Sta. Izabel (start point 20°30'27.62"S/51°18'23.84"W, ending point 20°30'25.91"S/51°19'15.01"W), in the municipality of Ilha Solteira (SP). The second transect was located at Experimental Station (FEPE) in Selvíria, MS, which belongs to São Paulo State University (Unesp), School of Engineering, Ilha Solteira (start point 20°24'23.55"S/51°23'32.12"W, ending point 20°23'39.43"S/51°23'16.52"W). Each transect was visited monthly in February, March and April 2016. The footprints were photographed and recorded, for later identification with the help of specialized guides (BECKER; DALPONTE, 1991; BORGES; TOMAS, 2001). The proportion of each species was established, and Shannon diversity and Jaccard similarity were calculated (MAGURRAN, 2013). The values of H_{10} ' between the sampling areas were compared using the "t" test proposed by Hutcheson (ZAR, 1996).

2.2 DIGITAL PHOTOGRAMMETRY

Footprints of four of the recorded medium and large carnivores from the Cerrado were subjected to the digital photogrammetry technique for the use in the field tests. The puma (Puma concolor), the ocelot (Leopardus pardalis), maned wolf (Chrysocyon brachyurus) and crab-eating fox (Cerdocyon thous). Footprints were obtained in two ways: 1) under controlled conditions, using clay plots and floral foam in the enclosures of the Centro de Conservação da Fauna Silvestre de Ilha Solteira; and 2) footprints recorded in natural conditions at FEPE during the survey.

To create the models, 48 photographs were taken at the perimeter of each footprint, using a Canon PowerShot SX40 HS with 16 Mpx quality and adjustable aperture, ISO and exposure. These photos were arranged in two series. The first series at an angle of 30 °, and the second at 50 ° in relation to the horizontal plane of the footprint (fig. 2). The images were digitally superimposed in the software Agisoft Photoscan Pro 1.1.6 following the four routine steps: image alignment, dense cloud generation, digital mesh generation and texture addition.

Figure 1. Studied area. a) Map of Brazil, highlighting the states of São Paulo and Mato Grosso do Sul; b) Detail of the area, showing both 1500m transects in c) FEPE and d) Fazenda Sta. Izabel, in detail.

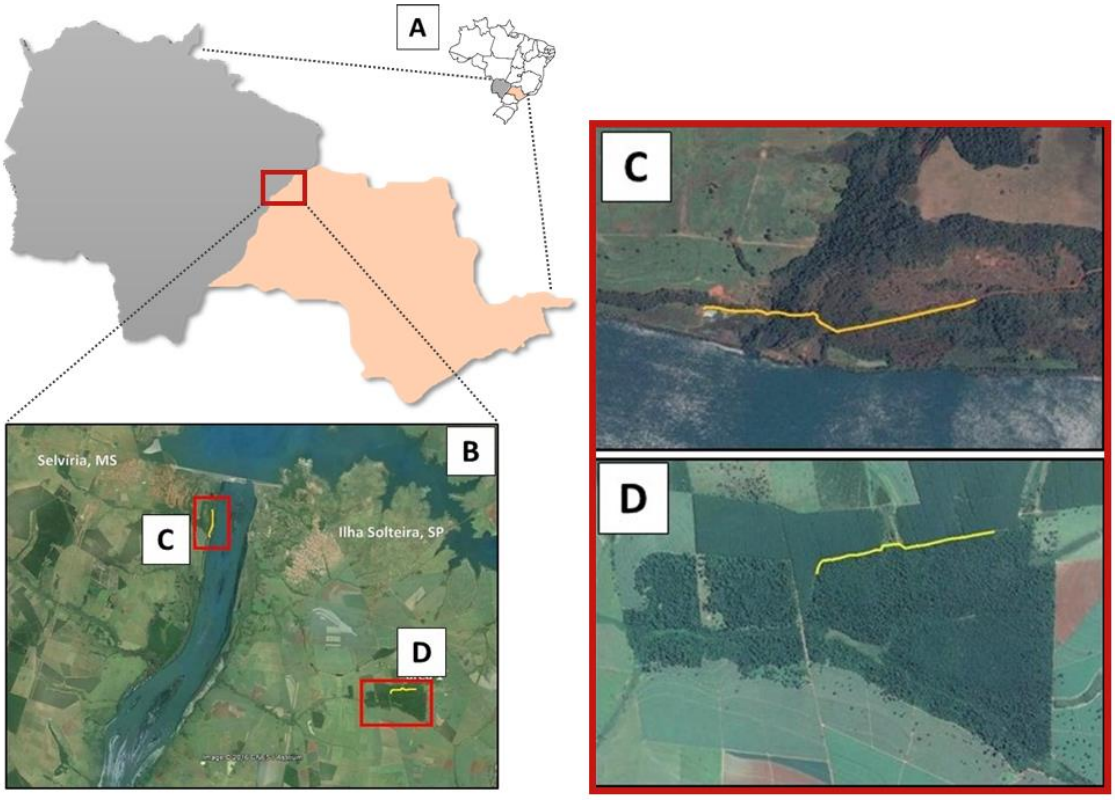
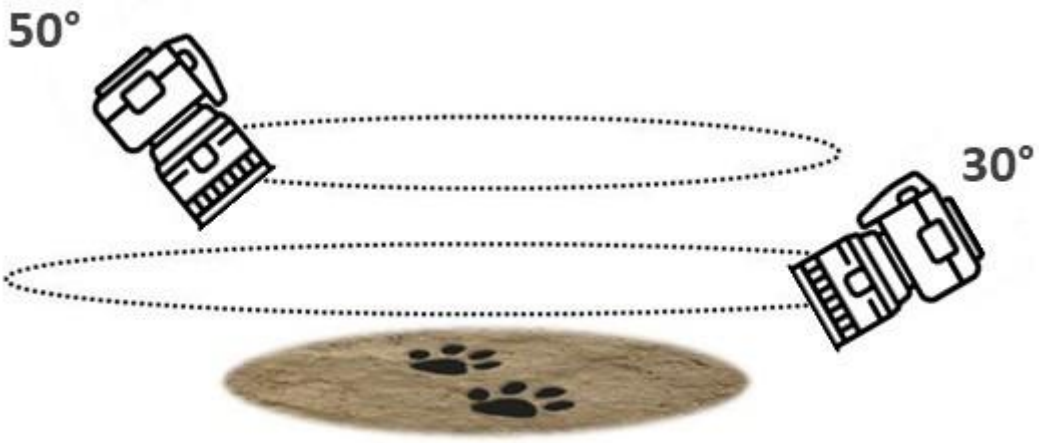


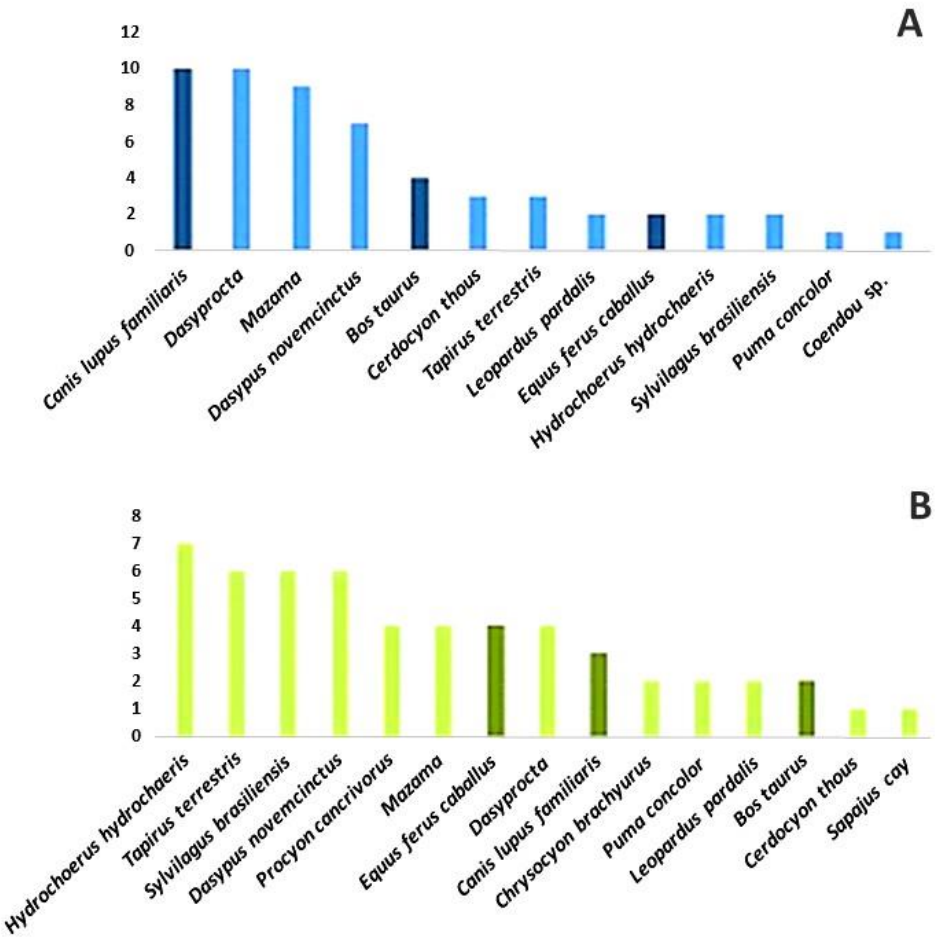
Figure 2. Scheme of the photography technique used to record the 48 footprint images for each photogrammetry model.



3 RESULTS AND DISCUSSION

Track surveys and analyses identified 13 species for Fazenda Sta. Izabel and 15 for FEPE (fig. 3), with Shannon's diversity index of H_{10}'= 0.88 and 1.01, respectively. The Jaccard similarity between sites was 0.75. The result of the Hutcheson t test was t=35.93 ($t_{0.05\ (2);\ 83}$ =1.98), indicating that the fauna composition differs significantly between analysed areas.

Figure 3. Total number of registers per species during the three months of study. a) Fazenda Sta. Izabel; b) FEPE. Dark tone columns represent domestic species recorded in the transects.



Most of the species were recorded in both studied sites (tab. 1), with the exception of the prehensile-tailed porcupine (Coendou sp.), recorded only in Fazenda Sta. Izabel, and the maned wolf (Chrysocyon brachyurus), crab-eating racoon (Procyon cancrivorus) and Azara's capuchin (Sapajus cay), recorded only in FEPE. The diversity of species recorded indicates that FEPE has a relatively more stable condition compared to the fragment of Fazenda Sta. Izabel (MAGURRAN, 2013). This could be attributed to the fact that the FEPE fragment is in a heterogeneous area when compared to Fazenda Sta. Izabel. FEPE is characterized by a mosaic of more complex environments, including natural and implanted pastures, Permanent Preservation Areas, close canopy forests, swamps and riparian forest (UNESP, 2012), while at Fazenda Sta. Izabel, the fragment is a close canopy forest completely surrounded by sugar cane and rubber tree monocultures (fig. 1).

Table 1. Taxa identified in both transects. DM indicates domestic species. Taxonomy according to Páglia et al. (2012).

Order	**Family**/Species	Site
Cingulata	**Dasypodidae**	
	Dasypus novemcinctus Linnaeus, 1758	SP, MS
Perissodactyla	**Tapiriidae**	
	Tapirus terrestris Linnaeus, 1758	SP, MS
	Equidae	
	Equus ferus caballus Linnaeus, 1758 **DM**	SP, MS
Artiodactyla	**Cervidae**	
	Mazama sp. Rafinesque, 1817	SP, MS
	Bovidae	
	Bos taurus Linnaeus, 1758 **DM**	SP, MS
Carnivora	**Canidae**	
	Chrysocyon brachyurus (Illiger, 1815)	MS
	Cerdocyon thous (Linnaeus, 1766)	SP, MS
	Canis lupus familiaris (Linnaeus, 1758) **DM**	SP, MS
	Procyonidae	
	Procyon cancrivorus (Cuvier, 1798)	MS
	Felidae	
	Puma concolor (Linnaeus, 1771)	SP, MS
	Leopardus pardalis (Linnaeus, 1758)	SP, MS
Primates	**Cebidae**	
	Sapajus cay (Illiger, 1815)	MS
Lagomorpha	**Leporidae**	
	Sylvilagus brasiliensis (Linnaeus, 1798)	SP, MS
Rodentia	**Caviidae**	
	Hydrochoerus hydrochaeris (Linnaeus, 1766)	SP, MS
	Dasyproctidae	
	Dasyprocta sp. Illiger, 1811	SP, MS
	Erethizontidae	
	Coendou sp.	SP

In both fragments, a large number of domestic animals were registered, such as dogs, horses and cattle. However, the presence of top predators, such as pumas (Puma concolor) and ocelots (Leopardus pardalis), as well as important seed dispersers, including Brazilian tapirs (Tapirus terrestris) and maned wolfs (Chrysocyon brachyurus) indicate that the community is still well structured, given the importance of these animals in maintaining the environment (STEVEN; PUTZ, 1984; DA FONSECA; ROBINSON, 1990; MOTTA-JUNIOR; MARTINS, 2002; KAGEYAMA; GANDARA, 2003;

O'FARRIL et al., 2013).

The application of photogrammetry allowed us to reconstruct in detail the footprints recorded. Relevant anatomical features for identification such as number and arrangement of pads, fingers and claws, were recovered reliably (fig. 4). The three-dimensional model allows access to the footprint at different angles, which is an advantage over field guides that offer only a comparison angle, commonly in linear drawings. (fig. 5). Still, the possibility of accessing the digital model in the field and the ease of sharing the models represent advantages in relation to plaster endocasts collections. Another possibility is the application of the digitalized models in the individual identification. In the past 15 years, the use of software-based analysis in individual footprint identification techniques, such as Footprint Identification Technique (FIT), produced consistent results with carnivores and perissodactyls (ALIBHAI et al. 2008, 2017; PIMM et al. 2015). Digital photogrammetry, as a novelty in the field, could expand this non-invasive approach. However, specific tests are necessary to guarantee its applicability.

Figure 4. Digital model of a footprint of maned wolf (Chrysocyon brachyurus) reconstructed by photogrammetry. a) Plantar view of the model; b) Detail of the plantar view; c-d) Virtual manipulation of the model two angles.

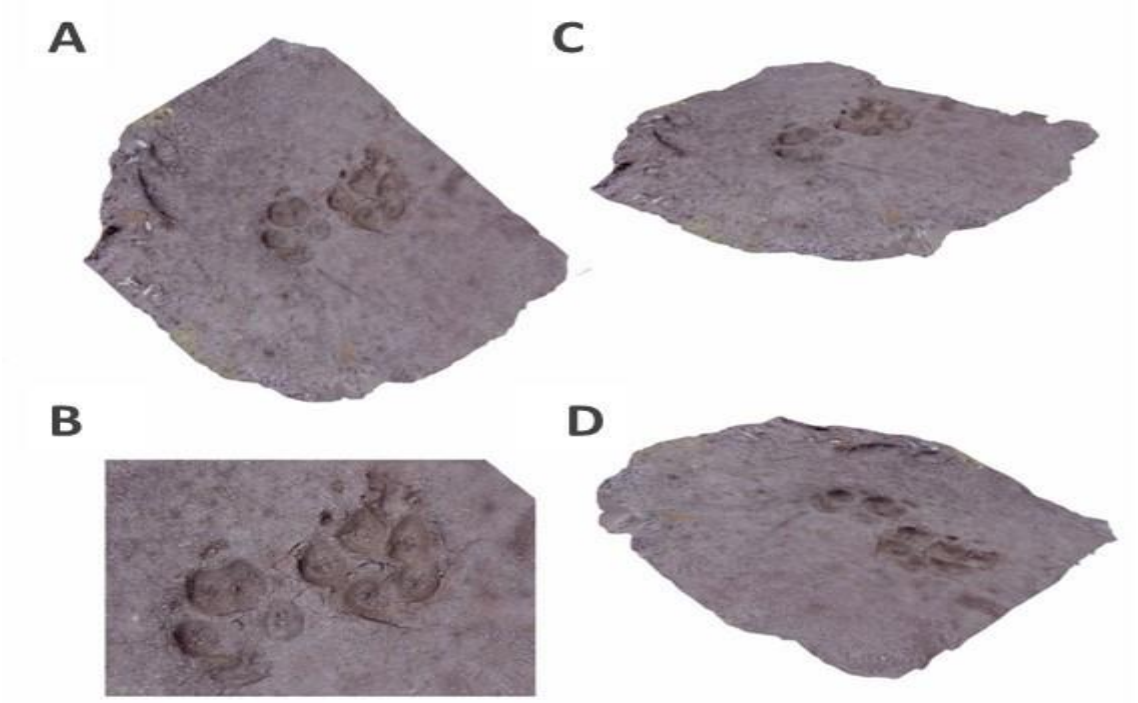
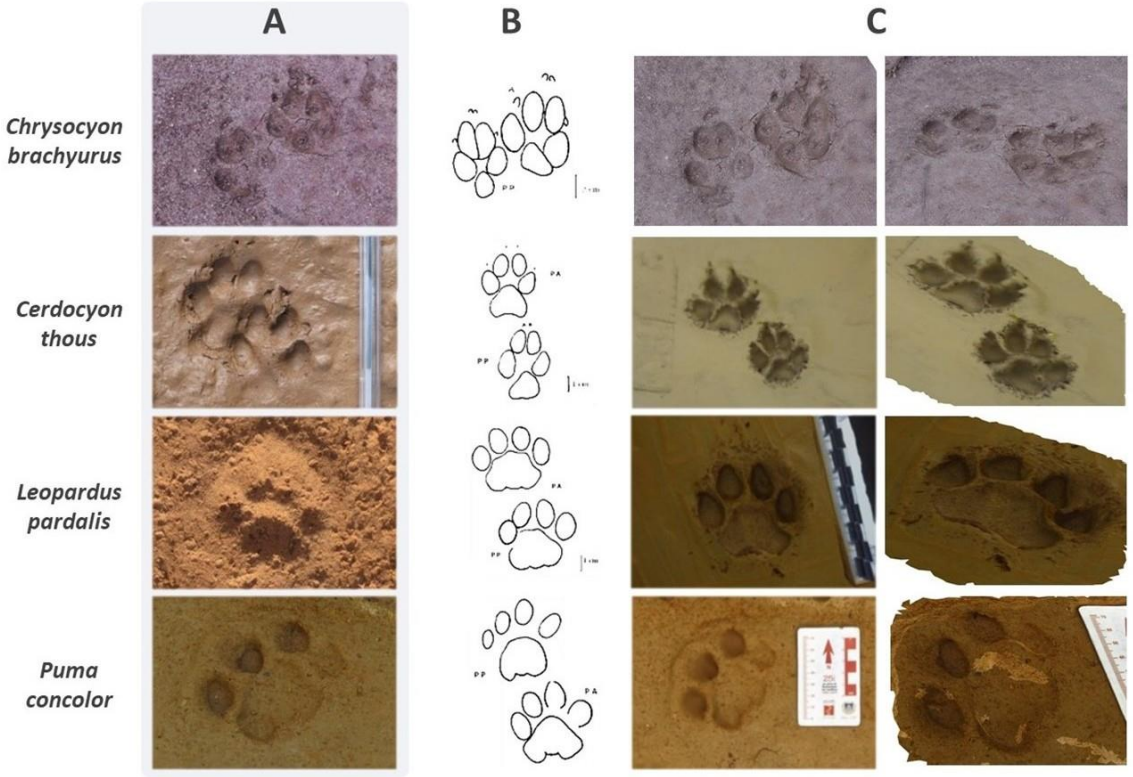


Figure 5. a) Footprints of the analysed species and their respective representations in b) field guides and c) three-dimensional models (showed in two angles). Illustrations adapted from Becker e Dalponte (1991).



4 CONCLUSIONS

Despite being located in degraded areas, both fragments present an important record of the medium and large mammals expected for the region. These results can assist in better planning to prevent these local populations from becoming extinct with the continuous and increasing human pressure in the region, as well as serve as a basis for future works of similar scope.

The application of the digital photogrammetry technique proved to be an interesting tool for the study of the footprints of medium and large mammals. These data present a good prospect for the use of three-dimensional models in the academic environment as a tool for identifying footprints in the field. Additionally, the results envisage its use also for environmental education and scientific outreach.

ACKNOWLEDGEMENTS

The authors wish to thanks the Centro de Conservação de Animais Silvestres de Ilha Solteira for the support provided in obtaining footprints and to the Guarda Municipal de Ilha Solteira for helping in the field work.

REFERENCES

ALIBHAI, Sky K.; JEWELL, Zoe C.; LAW, Peter R. A footprint technique to identify white rhino Ceratotherium simum at individual and species levels. Endangered Species Research, v. 4, n. 1-2, p. 205-218, 2008.

ALIBHAI, Sky; JEWELL, Zoe; EVANS, Jonah. The challenge of monitoring elusive large carnivores: An accurate and cost-effective tool to identify and sex pumas (Puma concolor) from footprints. PloS one, v. 12, n. 3, p. e0172065, 2017.

BECKER, M.; DALPONTE, J.C. Rastros de mamíferos silvestres brasileiros: um guia de campo. Brasília, DF: Editora Universidade de Brasília, 1991. 180 p.

BORGES, P.A; TOMAS, W.M. Guia de Rastros e Outros Vestígios de Mamíferos do Pantanal. Primeira Edição, Corumbá, MS. 2001, 139p;

DA FONSECA, G. A. B.; ROBINSON, J. G. Forest size and structure: Competitive and predatory effects on small mammal communities. Biological Conservation, v. 53, n. 4, p. 265-294, 1990.

KAGEYAMA, P.; GANDARA, F. B. Restauração e conservação de ecossistemas tropicais. In: CULLEN JR., L; RUDRAN, R.; VALLADARES-PADUA, C. (Eds.). Métodos de estudos em biologia da conservação e manejo da vida silvestre. Curitiba; Editora da Universidade Federal do Paraná. 2003.

KLEIN, H. et al. Archosaur footprints (cf. Brachychirotherium) with unusual morphology from the Upper Triassic Fleming Fjord Formation (Norian–Rhaetian) of East Greenland. Geological Society, London, Special Publications, v. 434, p. SP434. 1, 2015.

LALLENSACK, J. N. et al. Dinosaur tracks from the Langenberg Quarry (Late Jurassic, Germany) reconstructed with historical photogrammetry: Evidence for large theropods soon after insular dwarfism. Palaeontologia Electronica, v. 18, n. 2, p. 1-34, 2015.

MAGIOLI, Marcelo et al. Short and narrow roads cause substantial impacts on wildlife. Oecologia Australis, v. 23, n. 1, p. 99-111, 2019.

MAGURRAN, A. E. Medindo a diversidade biológica. UFPR. 2013.

MIOTTO, R. A. et al. Monitoring a puma (Puma concolor) population in a fragmented landscape in southeast Brazil. Biotropica, v. 44, n. 1, p. 98-104, 19 jan. 2012.

MORO-RIOS, R. F. et al. Manual de Rastros da Fauna Paranaense. Curitiba: Instituto Ambiental do Paraná, 2008. 70

MOTTA-JUNIOR, J. C.; MARTINS, K. The frugivorous diet of the manned Wolf, Chrysocyon brachyurus, in Brasil: ecology and conservation. Dispersal. In: LEVEY, D. J. Silva, W. R., GALETTI, M. (Ed.). Seed dispersal and frugivory: ecology, evolution and conservation. São Paulo: CABI Pub., 2002. P. 511.

MUNARI, D.P. Técnicas de monitoramento e a detecção de mamíferos terrestres na floresta Amazônica. 2008. Dissertação de Mestrado, Programa de Pós-Graduação em Biologia Tropical e Recursos Naturais, Universidade Federal do Amazonas, AM. 39pp. 2008

O'FARRIL, G.; GALETTI, M.; CAMPOS-ARCEIZ, A. Frugivory and seed dispersal by tapirs: an insight on their ecological role. Interactive zoology, v. 8, n. 1, p. 4-17, mar. 2013.

PIMM, Stuart L. et al. Emerging technologies to conserve biodiversity. Trends in ecology & evolution, v. 30, n. 11, p. 685-696, 2015.

PAGLIA, Adriano P. et al. Lista Anotada dos Mamíferos do Brasil 2ª Edição/Annotated Checklist of Brazilian Mammals. Occasional papers in conservation biology, v. 6, p. 1-82, 2012.

STEVEN, D. D.; PUTZ, F. E. Impact of Mammals on Early Recruitment of a Tropical Canopy Tree, Dipteryx panamensis, in Panama. Oikos, v. 43, n. 2., p. 207, 1 jul. 1984.

TROMBULAK, S. C.; FRISSEL, C. A. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology, v. 14, n. 1, p. 18-30, fev. 2000.

TURNER, I. M., CORLETT, R. The conservation value of small, isolated fragments of lowland tropical rainforest. Trends in Ecology & Evolution, v. 11, n. 8, p. 330-333, ago. 1996.

UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO" FACULDADE DE ENGENHARIA Câmpus de Ilha Solteira. RELATÓRIO BIANUAL DE UNIDADE AUXILIAR COMPLEXA PERÍODO: 2010 - 2011 FAZENDA DE ENSINO, PESQUISA E EXTENSÃO - FEPE. Ilha Solteira: Unesp, 2012. 597 p. Disponível em: https://www.feis.unesp.br/Home/Instituicao/administracao/congregacao/pautas/2012/08Extra280812/Anexo2_FEPE.pdf. Acesso em: 02 dez. 2020.

ZAR, J. H. Biostatistical Analysis. 3rd. Ed. New Jersey, Prentice Hall. 1996.