Human interference with wildlife surveys: a case study from camera-trapping road underpasses in Costa Rica

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Abstract Camera traps are widely used to study wildlife. However, theft and vandalism are frequent, resulting in millions of dollars in financial losses and large data gaps in research. Here we report on the impacts of camera-trap theft on a study examining wildlife movement under highway bridges in south-west Costa Rica. Even with metal cases, locks and signs installed on all camera traps, 65% were stolen. The working camera traps accumulated a total of 167 trap-nights and detected only two wild mammal species, eight bird species and one reptile species, as well as three domestic animal species and people. This limited number of wild species was unexpected given the known presence of wide-ranging megafauna and a diverse terrestrial mammal community in the region. The pervasive theft of camera traps leads to data gaps and impairs the potential for research in the region, and we discuss the potential additional reasons for detecting only a small number of species. Our findings highlight the need for solutions to camera-trap theft, to limit financial and data losses for conservation.

Resumen Las cámaras trampa son usadas mundialmente para el estudio de vida silvestre. Sin embargo, los robos y vandalismo de estos dispositivos son frecuentes, lo que representa una pérdida financiera de millones de dólares, y una significativa disminución de datos para la investigación científica. En este artículo, reportamos los impactos de robos de cámaras trampa en un estudio enfocado en movimiento de vida silvestre en pasos de fauna subterráneos localizados en carreteras del suroeste de Costa Rica. Aún con protección de cajas metálicas, cerraduras y señalización instalada en todas las cámaras trampa, el 65% de las cámaras fueron robadas. Las cámaras trampa que funcionaron acumularon un esfuerzo total de muestreo de 167 noches, detectando solamente dos mamíferos silvestres, ocho aves, un único reptil, así como tres especies de animales domésticos y personas. Este número limitado de especies silvestres fue inesperado dada la presencia conocida de una megafauna con grandes distribuciones y una comunidad diversa de mamíferos terrestres en la región. El robo generalizado de cámaras trampa genera lagunas en los datos y perjudica el potencial de investigación en la región, y discutimos las posibles razones adicionales de la detección limitada de especies. Los resultados de este estudio resaltan la necesidad de una solución para el fototrampeo en áreas donde la incidencia de robo es alta, con el fin de detener las pérdidas económicas y de datos para la conservación.

Keywords Camera theft, camera trapping, Costa Rica, data gaps, human disturbance, roads, wildlife surveys, wildlife underpasses

Camera traps are widely used to survey wildlife (Meek et al., 2015; Suzuki et al., 2017). However, theft and vandalism of cameras are frequent, significantly affecting studies both within (Hossain et al., 2016) and outside (Widodo et al., 2022) protected areas. An international study revealed that theft and vandalism not only incur costs because of equipment loss (c. USD 1.48 million from 309 practitioners during 2010–2015) and theft prevention (c. USD 800,000 during 2010–2015) but also affect survey design (Meek et al., 2018). However, wildlife surveys are more important than ever, particularly in human-dominated landscapes, if we are to establish human–wildlife coexistence despite increasing global urbanization rates (mean expansion rate of 9,687 km^2 per year for the past 30 years; Liu et al., 2020).

In particular, we need to understand how wildlife responds to movement barriers such as roads. Road underpasses and overpasses have been shown to mitigate the negative effects of roads on wildlife (Donaldson, 2007; Teixeira et al., 2013; Flatt et al., 2022). However, these structures are expensive and complex to build (Ascensão & Mira, 2007). Bridges have the potential to act as multiple-use structures. They are usually constructed by transportation companies and government agencies to facilitate human mobility over waterbodies. These bridges could also serve as underpasses for wildlife, providing dispersal routes. However, the most widely studied road underpasses are drainage coverts (Taylor & Goldingay, 2010; Sparks &

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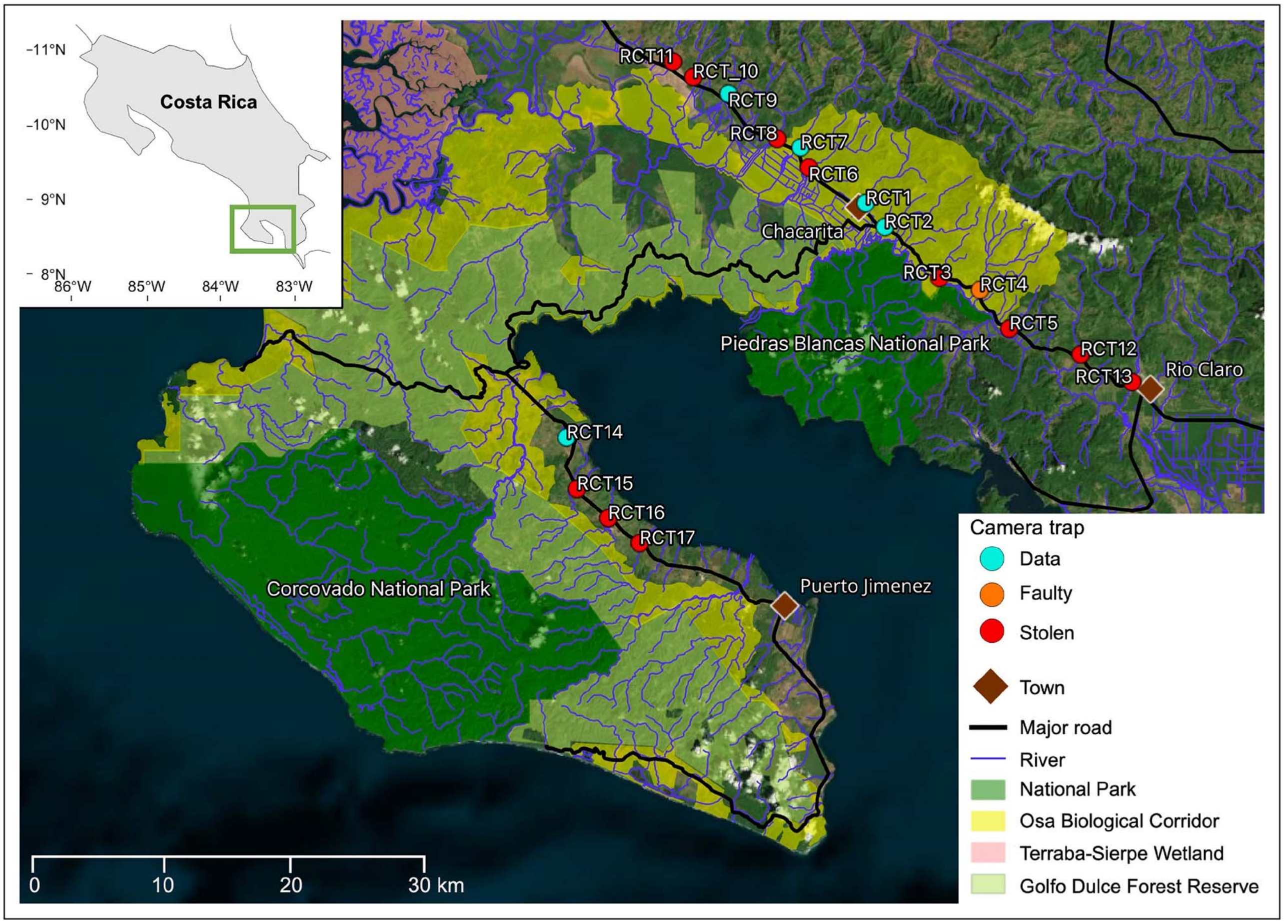

FIG. 1 Locations of camera traps installed in bridge underpasses, and of protected areas, in the Osa Peninsula, Costa Rica. (Readers of the printed journal are referred to the online article for a colour version of this figure.)

Gates, 2012; Denneboom et al., 2021; Monge-Velázquez & Saenz, 2022). Studies that have included bridges have been concentrated in North America (Warnock-Juteau et al., 2022) and Australia (Goldingay et al., 2022).

The Osa Peninsula is home to the largest remnant tract of Pacific lowland wet forest in Mesoamerica (Holdridge, 1967) and contains four protected areas (Fig. 1; Weissenhofer et al., 2001). The region is traversed by a network of unpaved roads and two paved highways: National Route 245 (7–8 m wide and stretching 77 km from Puerto Jimenez to Chacarita, overpassing 15 substantial rivers) and Inter-American Highway 2 (7–10 m wide and stretching 57 km from Sierpe to Rio Claro, overpassing 13 substantial rivers). A region-wide camera-trap study in 2018 verified the presence of wide-ranging megafauna species and documented 23 wild terrestrial mammal species (Vargas et al., 2022). The wildlife community is recovering throughout the region, with many species that were once restricted to Corcovado National Park now widespread across the landscape (Carrillo et al., 2000; Vargas et al., 2022). This confirms the presence of a mammal community that could utilize and benefit from safe road crossings for further dispersal.

We installed single camera-trap monitoring stations (Bushnell Trophy Cam HD Aggressor, Bushnell, USA; set

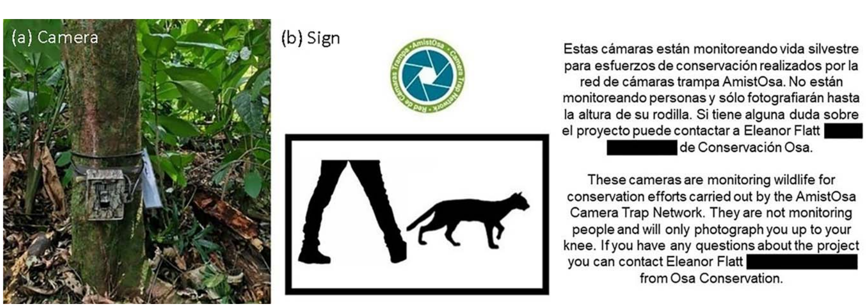

PLATE 1 Camera trapping with theft protection. (a) A camera trap from the study with a metal case, lock and laminated sign. (b) Close-up of the sign in (a), which explains the project in Spanish and English, with visual representations and a contact number (blacked out).

TABLE 1 Summary of all domestic and wild animal species detected by camera traps at five bridges monitored by camera traps in Osa Peninsula, Costa Rica (Fig. 1).

Bridge	Domestic species	Mammal species	Bird species	Reptile species
RCT1		Northern raccoon *Procyon lotor pumilus*	Bare-throated tiger heron *Tigrisoma mexicanum*, great-tailed grackle *Quiscalus mexicanus*	
RCT2	Dog		Black vulture *Coragyps atratus*, great-tailed grackle	
RCT7		Northern raccoon	Little blue heron *Egretta caerulea*	Green iguana *Iguana iguana*
RCT9	Dog	Northern raccoon	Bare-throated tiger heron, great-tailed grackle, little blue heron, snowy egret *Egretta thula*, white ibis *Eudocimus albus*	
RCT15	Dog, cattle, horse	Northern raccoon, White-nosed coati *Nasua narica*	Bare-throated tiger heron, black vulture, cattle egret *Bubulcus ibis*, great-tailed grackle, grey-necked wood-rail *Aramides cajaneus*	

to record 13 s videos, with 30 s resting periods) underneath 17 bridges along two paved highways in the Osa Peninsula for 4 months (February–May 2019) during the dry season, before the heavy rains caused the rivers to rise, which can make the underpasses inaccessible to people and wildlife (Fig. 1). The rivers were 13.5–21.6 m wide and bridge heights 4.95–7.54 m. We installed locks and informative signs on all camera traps to reduce the potential for theft (Plate 1).

Of the 17 camera traps, five obtained data, 11 were stolen and one broke, probably because of humidity or an electrical fault. The five working camera traps accumulated a total of 167 trap-nights (open habitat caused a high number of false triggers by quick-growing vegetation, and exposure to high temperatures and heavy rain resulted in short battery life). The camera traps detected two wild mammal species, eight bird species, one reptile species, three domestic species and people (Table 1). The two wild mammal species were habitat-generalist omnivores: the northern raccoon *Procyon lotor pumilus* and the white-nosed coati *Nasua narica*. The northern raccoon was detected under four of the bridges and was observed moving through these structures and foraging. The white-nosed coati was detected moving beneath just one of the bridges. Dogs were detected at three bridges, horses and cattle at one bridge and human activity (passing through and socializing) was detected at all five bridges from which we retrieved data.

We detected only two of the 23 wild terrestrial mammal species recorded in the region. This was surprising for two reasons: firstly, we conducted the study during the dry season, which is when the rivers are at their lowest, facilitating wildlife movements, and secondly, a similar study in the Guanacaste region of Costa Rica detected 14 mammal species using six drainage culverts (Monge-Velázquez & Saenz, 2022). Furthermore, the culverts in the Guanacaste region, just like the potential multiple-use structures surveyed in our study, were not built specifically for wildlife use, with no techniques being adopted to encourage wildlife movements (Monge-Velázquez & Saenz, 2022). The reasons for the low number of species detected in our study could be the surrounding land uses (cattle farming, agriculture and small towns) and the fact that the bridges are not established wildlife crossings. It is possible that species might risk crossing the roads in preference to using underpasses. Strategically placed fencing or tree planting, which are proven techniques for funnelling wildlife (Littlewood et al., 2020), could help promote wildlife use of these underpasses. However, the principal reason for the low number of species detected is the limited number of cameras and trap-nights because of the theft of 65% of the camera traps.

Theft was significant despite the installation of security cases, locks and signs. Even with these security measures, this study resulted in a financial loss of USD 2,970 (the total material cost of the study was USD 4,590, with USD 1,020 of this invested specifically in theft protection). There was also a cost in terms of the missed opportunity to contribute knowledge on wildlife movement and to use this to improve underpasses to facilitate their use by wildlife. To reduce camera-trap theft, some studies have installed camera traps at greater heights than usual, to avoid their detection by people, but this has resulted in a dramatic decrease in wildlife detections (Meek et al., 2016). Studies that focus on nocturnal species have collected the deployed camera traps each day to limit their theft (Athreya et al., 2013), but this is not a suitable or sustainable solution for large-scale studies assessing multiple species. However, a security post for camera traps, installed in a bollard-style housing to limit theft, has been developed and is proving successful (Meek et al., 2022). Perhaps the best potential solution to combat camera-trap theft is the development of small and cryptic camera traps that can evade detection by people but still detect wildlife. Conservation organizations are making advances in camera-trap technology to develop improved camera traps (Meek & Pittet, 2012), but there is still work to be done to make these solutions accessible and scalable (Curnick et al., 2022; Westworth et al., 2022). These improvements will limit resource losses and fill data gaps in wildlife surveys conducted in areas where the chance of theft of equipment is high.

Author contributions Study design: all authors; fieldwork: EF, HB; data analysis: EF; writing: EF, AW.

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Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards. Although we collected data on people, this was not intentional. We conducted this study in a socially responsible manner that did not violate privacy or cause other unnecessary harm, and we deleted all photographs of people.

Data availability Raw and extracted data are available from the corresponding author upon request.

References

ASCENSÃO, F. & MIRA, A. (2007) Factors affecting culvert use by vertebrates along two stretches of road in southern Portugal. *Ecological Research*, 22, 57–66.

ATHREYA, V., ODDEN, M., LINNELL, J.D., KRISHNASWAMY, J. & KARANTH, U. (2013) Big cats in our backyards: persistence of large carnivores in a human dominated landscape in India. *PLOS One*, 8, e57872.

CARRILLO, E., WONG, G. & CUARÓN, A.D. (2000) Monitoring mammal populations in Costa Rican protected areas under different hunting restrictions. *Conservation Biology*, 14, 1580–1591.

CURNICK, D.J., DAVIES, A.J., DUNCAN, C., FREEMAN, R., JACOBY, D.M., SHELLEY, H.T. et al. (2022) SmallSats: a new technological frontier in ecology and conservation? *Remote Sensing in Ecology and Conservation*, 8, 139–150.

DENNEBOOM, D., BAR-MASSADA, A. & SHWARTZ, A. (2021) Factors affecting usage of crossing structures by wildlife – a systematic review and meta-analysis. *Science of the Total Environment*, 777, 146061.

DONALDSON, B. (2007) Use of highway underpasses by large mammals and other wildlife in Virginia: factors influencing their effectiveness. *Transportation Research Record*, 2011, 157–164.

FLATT, E., BASTO, A., PINTO, C., ORTIZ, J., NAVARRO, K., REED, N. et al. (2022) Arboreal wildlife bridges in the tropical rainforest of Costa Rica's Osa Peninsula. *Folia Primatologica*, 1, 1–17.

GOLDINGAY, R.L., ROHWEDER, D., TAYLOR, B.D. & PARKYN, J.L. (2022) Use of road underpasses by mammals and a monitor lizard in eastern Australia and consideration of the prey-trap hypothesis. *Ecology and Evolution*, 12, e9075.

HOLDRIDGE, L.R. (1967) *Life Zone Ecology* (revised edition). Tropical Science Center, San Jose, Costa Rica.

HOSSAIN, A.N.M., BARLOW, A., BARLOW, C.G., LYNAM, A.J., CHAKMA, S. & SAVINI, T. (2016) Assessing the efficacy of camera trapping as a tool for increasing detection rates of wildlife crime in tropical protected areas. *Biological Conservation*, 201, 314–319.

LITTLEWOOD, N.A., ROCHA, R., SMITH, R.K., MARTIN, P.K., LOCKHART, S.L., SCHOONOVER, R.F. et al. (2020) *Terrestrial Mammal Conservation: Global Evidence for the Effects of Interventions for Terrestrial Mammals Excluding Bats and Primates*. Open Book Publishers, Cambridge, UK.

LIU, X., HUANG, Y., XU, X., LI, X., LI, X., CIAIS, P. et al. (2020) High-spatiotemporal-resolution mapping of global urban change from 1985 to 2015. *Nature Sustainability*, 3, 564–570.

MEEK, P.D. & PITTET, A. (2012) User-based design specifications for the ultimate camera trap for wildlife research. *Wildlife Research*, 39, 649–660.

MEEK, P.D., BALLARD, G.A., VERNES, K. & FLEMING, P.J. (2015) The history of wildlife camera trapping as a survey tool in Australia. *Australian Mammalogy*, 37, 1–12.

MEEK, P.D., BALLARD, G.A. & FALZON, G. (2016) The higher you go the less you will know: placing camera traps high to avoid theft will affect detection. *Remote Sensing in Ecology and Conservation*, 2, 204–211.

MEEK, P.D., BALLARD, G.A., SPARKES, J., ROBINSON, M., NESBITT, B. & FLEMING, P.J. (2018) Camera trap theft and vandalism: occurrence, cost, prevention and implications for wildlife research and management. *Remote Sensing in Ecology and Conservation*, 5, 160–168.

MEEK, P.D., BALLARD, G.A., ABELL, J., PERRIE, S., BLACKFORD, A., JONES, R. & FLEMING, P.J.S. (2022) Mitigating camera trap loss using permanent security posts: 10 years of development. *Australian Mammalogy*, 44, 407–412.

MONGE-VELÁZQUEZ, M. & SAENZ, J. (2022) Drainage culverts as a measure to avoid mammal roadkills in Costa Rica: the case of *Dasyprocta punctata*. *Therya Notes*, 3, 66–69.

SPARKS, J.L. Jr & GATES, J.E. (2012) An investigation into the use of road drainage structures by wildlife in Maryland, USA. *Human–Wildlife Interactions*, 6, 311–326.

SUZUKI, A., THONG, S., TAN, S. & IWATA, A. (2017) Camera trapping of large mammals in Chhep Wildlife Sanctuary, northern Cambodia. *Cambodian Journal of Natural History*, 1, 63–75.

TAYLOR, B.D. & GOLDINGAY, R.L. (2010) Roads and wildlife: impacts, mitigation and implications for wildlife management in Australia. *Wildlife Research*, 37, 320–331.

TEIXEIRA, F.Z., PRINTES, R.C., FAGUNDES, J.C.G., ALONSO, A.C. & KINDEL, A. (2013) Canopy bridges as road overpasses for wildlife in urban fragmented landscapes. *Biota Neotropica*, 13, 117–123.

VARGAS SOTO, J.S., BEIRNE, C., WHITWORTH, A., CRUZ DIAZ, J.C., FLATT, E., PILLCO-HUARCAYA, R. et al. (2022) Human disturbance and shifts in vertebrate community composition in a biodiversity hotspot. *Conservation Biology*, 36, e13813.

WARNOCK-JUTEAU, K., BOLDUC, V., LOSCERBO, D., ANDERSON, M., DAGUET, C. & JAEGER, J.A. (2022) Co-use of existing crossing structures along roads by wildlife and humans: wishful thinking? *Nature Conservation*, 47, 235–270.

WEISSENHOFER, A., HUBER, W., WEBER, A. & GONZALEZ, J. (2001) A brief outline of the flora and vegetation of the Golfo Dulce region. In *An Introductory Field Guide to the Flowering Plants of the Golfo Dulce Rain Forests Costa Rica: Corcovado National Park and Piedras Blancas National Park* (eds A. Weber, W. Huber, A. Weissenhofer, N. Zamora & G. Zimmermann), pp. 15–24. Biologiezentrum des Oberösterr eichischen Landesmuseums, Linz, Austria.

WESTWORTH, S.O., CHALMERS, C., FERGUS, P., LONGMORE, S.N., PIEL, A.K. & WICH, S.A. (2022) Understanding external influences on target detection and classification using camera trap images and machine learning. *Sensors*, 22, 5386.

WIDODO, F.A., IMRON, M.A., SUNARTO, S. & GIORDANO, A.J. (2022) Carnivores and their prey in Sumatra: occupancy and activity in human-dominated forests. *PLOS One*, 17, e0265440.