Tracks, Scats, and Dens in the City: Challenges, Strategies, and Opportunities Identified from Trailing Urban Coyotes in Edmonton, Canada

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(PAPER) Tracks, Scats, and Dens in the City: Challenges, Strategies, and Opportunities Identified from Trailing Urban Coyotes in Edmonton, Canada

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Abstract
The value of wildlife tracking is increasingly recognized in modern wildlife science, but it remains underutilized in some areas of study. Following animal trails (i.e., trailing) in snow is a promising method to study the ecology and behaviour of urban wildlife. I describe the challenges I encountered and the techniques I used to address them while trailing urban-adapted coyotes (*Canis latrans*) in Edmonton, Alberta, Canada. I followed 530 km (329 miles) of coyote trails to detect dens (n = 120), scats (n = 1263), and coprophagy of coyote scats by black-billed magpies (*Pica hudsonia*). I describe challenges associated with trailing in a city, including limited refugia, high animal density, elevated human traffic, scat identification for animals consuming anthropogenic food, dense vegetation associated with young forest, and private land. I also describe two challenges associated with trailing in cold temperatures: management of eyewear, and sound. Lastly, I describe the importance of considering people experiencing homelessness and the elevated prevalence of zoonotic disease in cities. Many of these challenges can be addressed through planning, back trailing, and statistical designs that compare used and available habitat. When these challenges are addressed, trailing in snow is an effective method to study urban wildlife. I hope this summary supports the further use of trailing in scientific study and ecological research.

Background:
The value of wildlife tracking is increasingly recognized in modern wildlife science (Liebenberg et al. 2017; Lawrence 2020). Its use has been supported by the development and expansion of the CyberTracker system, which provides rigorous and standardized assessment of wildlife tracking skills (Elbroch and Wittmer 2013; Elbroch, Lendrum, et al. 2015; Elbroch, Lowrey, et al. 2018), and promotes increased data quality and greater replicability in tracking-based studies (Evans et al. 2009; Elbroch, Mwampamba, et al. 2011; Elbroch, Lowrey, et al. 2018). The applications of wildlife tracking for scientific study are diverse, including habitat selection (Wolf and Ale 2009), animal behaviour (Clapham et al. 2014), occupancy and abundance (Jhala et al. 2011), and intraspecific differences (Alibhai et al. 2017). Compared to methods that involve capturing and collaring wildlife, tracking approaches are minimally invasive.

One method of using tracking to study wildlife is trailing, which involves following a series of tracks and signs left by an animal (Liebenberg et al. 2010). Besides the movement information derived from the path followed (Whittington et al. 2004), observers following trails detect signs left by the animal, such as dens (Raymond and St. Clair 2023*b*), kill sites (Allen et al. 2015), and marking sites (Bowen and Cowan 1980; Wolf and Ale 2009). Because researchers must access sufficient high-quality substrate to efficiently trail animals, ecological studies employing trailing typically occur in arid climates with extensive sand or dust, or where snow persists during the winter (Long et al. 2012).

Cities are an environment where trailing in snow may be particularly effective. Urbanization is increasing globally (United Nations 2019), with myriad effects on wildlife and biodiversity (McKinney 2006), leading to increased study of urban ecosystems. Studying urban wildlife presents unique challenges. For example, capturing and collaring animals in cities can be perceived negatively by the public (Cooke et al. 2017), and wildlife cameras used to study urban wildlife (Gaynor et al. 2018; Magle et al. 2019) are often stolen (Meek et al. 2019) and frequently capture humans and domestic pets, which reduces image processing efficiency and introduces privacy concerns. By contrast, trailing in snow is non-invasive, requires no special equipment, and is rarely noticed by members of the public.

In this paper, I describe techniques I used while trailing urban coyotes (*Canis latrans*) to study their ecology, habitat selection, and behaviour in Edmonton, Alberta, Canada (Raymond and St. Clair 2023*a*, 2023*b*, 2023*c*; Raymond et al. 2024), which included limited refugia, high animal density, high human traffic, atypical scat morphology, dense vegetation associated with young forest, and private land. I also include strategies for managing eyewear and sound when trailing in cold temperatures—topics that do not seem to be addressed in other resources about snow tracking (Long et al. 2012; Elbroch and McFarland 2019). Lastly, I describe two additional considerations when trailing in urban environments: the camps of people experiencing homelessness and zoonotic disease. Solutions include careful planning, back trailing, and strategic analytical approaches. I hope this summary fosters the use of trailing in ecological study and promotes its further use in urban wildlife research.

Study Area and Methods
I trailed coyotes in Edmonton, which is a large (684.4 km^2), sprawling city home to approximately 1 million people (City of Edmonton 2019). Edmonton lies at the interface of two major ecosystems, with grasslands to the south and boreal forest to the north. It is the northernmost city of > 1 million people in North America. The climate is dry and characterized by cold winters (Jan average temperature = –10.4°C / 13.3 °F) and warm summers (Jul average temp = 17.7 °C / 63.9 °F; Environment Canada 2022). Snow is typically present from December through March and may be present in November and April. Long winter cold snaps may occur. For example, during a stretch of fieldwork between December 2021 and January 2022, 13 of 15 days had high temperatures below –20 °C (–4 °F) and lows that felt like –45 °C (–49 °F) with the wind chill (Classen 2022). Edmonton includes extensive green spaces and naturalized areas (City of Edmonton 2014), which provide habitat for many species, including coyotes, white-tailed deer (*Odocoileus virginianus*), porcupines (*Erethizon dorsatum*), beavers (*Castor canadensis*), snowshoe hare

(*Lepus americanus*), white-tailed jackrabbits (*Lepus townsendii*), red squirrel (*Tamiasciurus hudsonicus*), and black-billed magpie (*Pica hudsonia*).

I trailed coyotes when snow was present between December 2020 and April 2022. I first used satellite imagery to detect high-quality habitat patches for coyotes, such as parks, natural areas, golf courses, abandoned lots, industrial yards, ditches, and alleys within city limits (Raymond et al. 2023*b*, 2023*c*; Raymond et al. 2024). I walked a central human path or road until I found coyote tracks, which I identified based on morphology, while also considering gait and ancillary evidence (Elbroch and McFarland 2019). I then used trailing techniques (Liebenberg et al. 2010) to follow tracks while recording trails using GPS on a mobile phone. I paused recording when I lost the trail. I followed a total of 530 km (329 miles) of trails, and I found 120 dens (Raymond and St. Clair 2023*b*), 1263 scats (Raymond et al. 2024), and 249 instances of magpies feeding on scats (Raymond and St. Clair 2023*c*).

Challenges of Trailing in Urban Environments

Limited refugia: Urban areas feature patches of high-quality habitat (e.g., parks, green spaces, natural areas) within an urban matrix (i.e., developed areas) that is less hospitable for wildlife (Nielsen et al. 2014). Wildlife often rest in these habitat patches during the day and increase nocturnal activity, when human activity declines (Gaynor et al. 2018). When these habitat patches are small, observers trailing animals should consider the possible consequences of unintentionally flushing an animal from its bed (Figure 1A; Table 1). An animal fleeing from a bed in a small green space may enter the adjacent urbanized matrix, where it could encounter vehicles, people, or domestic pets, potentially resulting in conflict. This risk increases when small, isolated green spaces occur near areas used by vulnerable demographics, such as children (Baker and Timm 2017) or dogs (Frauenthal et al. 2017). I once followed a fresh coyote trail to a small green space near an elementary school. I was downwind of a thick, brushy patch of vegetation, where I suspected animals were bedded. To avoid flushing animals into the schoolyard, I did not approach, but I later returned to the site outside of school hours and, as expected, found a cluster of coyote beds.

To avoid displacing animals into unsafe habitat, observers can use back trailing, which involves following an animal's tracks opposite their direction of travel. Back trailing is especially valuable in small green spaces surrounded by developed areas and when trailing during peak human activity (i.e., daytime). In cities, I typically use forward trailing when habitat patches are sufficiently large that flushed animals could find new bedding sites without entering the human-dominated matrix, such as golf courses and large parks. For scientific studies, statistical designs that compare locations the animal selected to areas that were available to the animal (i.e., use-available designs) are efficient because they allow the observer to stop following the trail as needed. Surveys that use transects or similar do not provide this flexibility.

Animal density: Cities contain plentiful resources for urban-adapted animals (Lowry et al. 2013), which enables animals to meet their nutritional needs in smaller areas, leading to small home ranges (Salek et al. 2015; Lowry et al. 2013) and high animal density. In the suburbs of Chicago, average coyote home range size was 2.31 km^2 (0.89 $miles^2$) compared to 3.24 km^2 (1.25 $miles^2$) in nearby rural areas (Ellington and Gehrt 2019). An advantage of high animal density is that animal use sites are abundant. For example, I detected approximately 3 scats per kilometer of coyote trail (Raymond et al. 2024), and another study yielded only 1.58 scats per kilometer of trail in Jasper National Park, Canada (Bowen and Cowan 1980). Unfortunately, high animal density complicates trailing, especially in the forested or naturalized parts of an animal's home range, which are disproportionately used (Dodge and Kashian 2013; Murray et al. 2015), or when the observer must stay on a specific individual's trail (Figure 1B; Table 1). To address high animal density, study designs ideally should not require identification of individual animals. Because high animal density also leads to tracks of various ages accumulating along the same paths, designs that allow the observer to follow tracks of any age are most efficient.

Human traffic: In addition to high animal density, the abundance of human and vehicle traffic renders trailing in cities challenging (Figure 1C; Table 1). In very developed parts of the city, human density and snow removal quickly obscure or remove tracks, giving the observer a limited temporal window for efficient data collection. This challenge is exacerbated at high latitudes in the winter when dawn occurs after many people have travelled to work, walked their dog, or engaged in other activities that deteriorate substrate quality. To limit the impacts of human traffic on data collection, I used the weather forecast to plan activities around snow events. Following fresh snow, I targeted areas with high human traffic (i.e., more developed areas), as the substrate deteriorated most quickly in these areas. I trained myself to use 'ugly tracks' and to follow aged trails (Liebenberg et al. 2010), which lengthened the period for data collection following a snow event. I often arrived at sites by dawn. Urban trailing is much easier in green spaces compared to developed areas, which is a limitation that should be addressed in the study design, or when discussing results.

Scat identification for animals consuming anthropogenic food: Scat identification in cities can be difficult when animals consume anthropogenic food. Anthropogenic food sources for coyotes range from food items reminiscent of their natural diet, such as non-native fruit (e.g., crabapples) to foods rarely encountered in the wild, like birdseed, compost, and garbage (Raymond et al. 2024). Diet drastically affects scat morphology (Elbroch and McFarland 2019), rendering species identification from scat difficult or impossible. For example, deer pellets and coyote scats are typically easily distinguished, but when these species eat birdseed, their weathered scats both resemble disorganized piles of poorly digested birdseed. When coyotes eat processed anthropogenic foods (e.g., bread products, cooked meat, kibble for pets), their scats lose the ropey, twisted, and tapered appearance that results from a natural prey diet (Elbroch and McFarland 2019). Like coyote scats containing fruit, these scats are blunt, tubular, and straight-sided (Elbroch and McFarland 2019; Figure 1D; Figure 2; Table 1).

Observers should retain flexibility about expected scat morphology and look for multiple lines of evidence to support scat identification. While scat size, shape, morphology, and colour are highly variable, foot morphology is not, and I often used tracks to support scat identification. In my studies, I minimized type 1 error (i.e., false positives) by including only scats that I was confident belonged to coyotes. This approach presumably led to increased type 2 error (i.e., false negatives), especially when scats were morphologically atypical because of their content. Study objectives can inform data collection procedures, methods should be transparent and applied consistently, and any limitations associated with the selected approach can be reported. Large sample sizes dilute the effects of occasional misclassification.

Dense understorey: The green spaces and naturalized areas in Edmonton are primarily composed of young forest with early seral structure (City of Edmonton 2014), which is characterized by high woody plant density and a thick, shrubby understorey (Province of British Columbia 2010). This vegetation structure is common in urban green spaces and is challenging when trailing (Figure 1E; Table 1). Urban wildlife are relatively small (i.e., deer-sized or smaller), so observers must adapt to efficiently follow animals through dense, thick vegetation, ideally without making undue noise. Clothing that allows observers to comfortably and safely navigate the terrain and vegetation selected by medium-sized, agile, quadrupeds is essential for urban trailing. Eyewear (i.e., glasses or sunglasses) protects eyes, and a balaclava can protect the face, ears, and nose, though it decreases auditory and olfactory acuity. Clothing that does not snag on vegetation is important; I wear a cruiser vest with external pockets for some field work, but, when trailing, a cruiser vest would easily become snagged on vegetation. Down jackets (or similar synthetic jackets) are easily torn by branches, allowing the fill to escape, and thus make poor outer layers. I generally wear an old windbreaker or a thick fleece as my outermost layer, both of which protect warm layers below. Speculative tracking, in which one anticipates where an animal is going, leaves the trail, and re-joins the trail where the terrain or vegetation improves, can be useful, but GPS recording should be paused while off trail. Back trailing can be useful because moving through this vegetation can be loud.

Private land: The ubiquity and extent of private land is a major challenge when trailing in cities. I have frequently followed wildlife trails adjacent to private land, such as at the ecotone between naturalized areas and residential neighbourhoods (Raymond and St. Clair 2023*a*). When trails enter private land, it is typically the end of the trail, which is often frustrating (Figure 1F; Table 1). To avoid trespassing, observers should be aware of land ownership and borders between public and private land. When trailing near such borders, I check mapping software frequently. I sometimes use binoculars to assess where an animal's trail goes on private land, and then use speculative tracking to pick up the animal's tracks on public land beyond the private area.

Challenges of Trailing in Cold Temperatures

Eyewear: Management of eyewear when trailing in cold temperatures is a persistent challenge. I use prescription glasses, but some type of protective eyewear is extremely valuable for preventing eye injury while trailing, and sunglasses reduce glare reflected off snow. In low temperatures, a balaclava protects against frostbite, but breathing can then cause eyewear to fog, obscuring vision. Striking a balance between a warm face and clear vision is challenging. I typically cover my face and remove my glasses when circumstances allow. These circumstances include a trail that is relatively easy to see and vegetation that is sufficiently thin that I can traverse it without risk of eye injury. When these circumstances are not met, I typically accept the discomfort of a cold face, monitor for frostbite, and stop to warm my skin as needed. Liebenberg et al. (2010) state that "tolerating a degree of pain and discomfort without flinching is part of being a traditional hunter" (p. 154); the same may be true of trailing animals in very cold temperatures.

Sound Management: Another challenge of trailing animals in cold temperatures is sound control. Being quiet is difficult on cold days; cold snow crunches beneath the feet, clothing layers increase sounds of material rubbing together, and snowshoes, if worn, are notoriously noisy. Branches are more brittle in cold air; when broken, they crack loudly—a phenomenon related to cellular water freezing and tension stress (Kubler 1983). Sound waves may also travel further on cold days (Wong and Embleton 1985). Because animals expend considerable energy to thermoregulate in the cold (Bekoff and Wells 1981), the potential costs of disruption are higher. Back trailing is one solution to the challenge of being quiet on cold days. When the weather is very cold, I avoid trailing in 'high consequence areas', which I define as sites where disrupting an animal is likely to cause displacement (e.g., small green spaces within heavily urbanized areas) and preferentially trail animals in larger naturalized areas.

Other considerations:

People experiencing homelessness: When tracking in cities, I often encounter evidence of people experiencing homelessness, who may camp and live in urban green spaces that are also selected by wildlife (Raymond and St. Clair 2024). I have never had a negative interaction with someone experiencing homelessness while trailing, but this demographic experiences higher rates of mental health challenges and substance use (Guillén et al. 2020). Many tangible and intangible characteristics will affect an observer's sense of safety and risk analysis while trailing in cities, and observers should thus be empowered to autonomously assess risk and make decisions in the field. I do not approach camps unless they are clearly abandoned, which can be determined based on the freshness of human tracks, weathering of the site given recent snowfall, and evaluating evidence of wildlife accessing the camp. This evaluation can be completed at a distance that would not disturb a camp occupant, if present. Because of their potential role in human-wildlife conflict, I often investigate abandoned camps for evidence of human-wildlife interactions (Raymond and St. Clair 2024).

Disease: Animal disease is elevated in cities (Albery et al. 2022) courtesy of high animal density, limited biodiversity, elevated stress levels, and altered community structure (Bradley and Altizer 2007). Access to anthropogenic food, which can limit immunity, and aggregations of feeding animals also increase animal disease (Murray et al. 2019). Zoonotic diseases, which can be transmitted between animals and humans, are therefore concerning in urban wildlife studies. Zoonotic host diversity is higher in cities (Gibb et al. 2020), and several common urban-adapted species carry diseases that can be lethal to humans. For example, in Edmonton, over 50% of coyotes are infected with *Echinococcus multilocularis* (Luong et al. 2020), a parasitic tapeworm that causes alveolar echinococcosis, which is an emerging infectious disease in North America (Houston et al. 2021). Trackers often have a healthy interest in animal sign, including scats, urine, and carcasses. I consider this interest positive, but high rates of zoonotic diseases suggest that caution is warranted in cities. I encourage trackers to empower themselves with knowledge about the zoonotic diseases present in their area, the species that can transmit them, and the mechanism(s) of infection, all of which can allow observers to take logical precautions that do not interfere with data collection or an appreciation of urban wildlife.

Conclusions

Increasing global urbanization and spatial overlap between people and wildlife highlight the importance of urban ecological research, but cities hold unique challenges for wildlife researchers. I trailed urban coyotes in snow to learn about habitat selection, marking behaviour, diet, and interspecific relationships. This body of work demonstrates the potential utility of trailing to answer scientific questions about urban-adapted species. Although trailing in cities can be challenging, techniques described in this paper can mitigate the impacts of these limitations. Many more innovations and strategies will likely be identified as trailing in urban environments increases.

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Tables and Figures:

Table 1. Challenges and solutions associated with trailing in urban environments.

Challenge	Solution(s)
Limited refugia	● Back trailing ● Analyze data using a use- available design
High animal density	● Study design that does not require individual identification
High human traffic	● Use weather forecasts to plan ● Prioritize developed areas as soon as possible after snow events ● Practice following old trails and ‘ugly’ tracks ● Begin at dawn
Scat identification for animals consuming anthropogenic food	● Expect deviations from ‘typical’ scat morphology ● Use multiple lines of evidence (e.g., tracks) ● Large sample sizes
Dense vegetation associated with young forest	● Protective eye wear ● Avoid external pockets ● Wear a durable outermost layer ● Speculative tracking ● Back trailing
Private land	● Speculative tracking (informed by binoculars) ● Frequent map reference

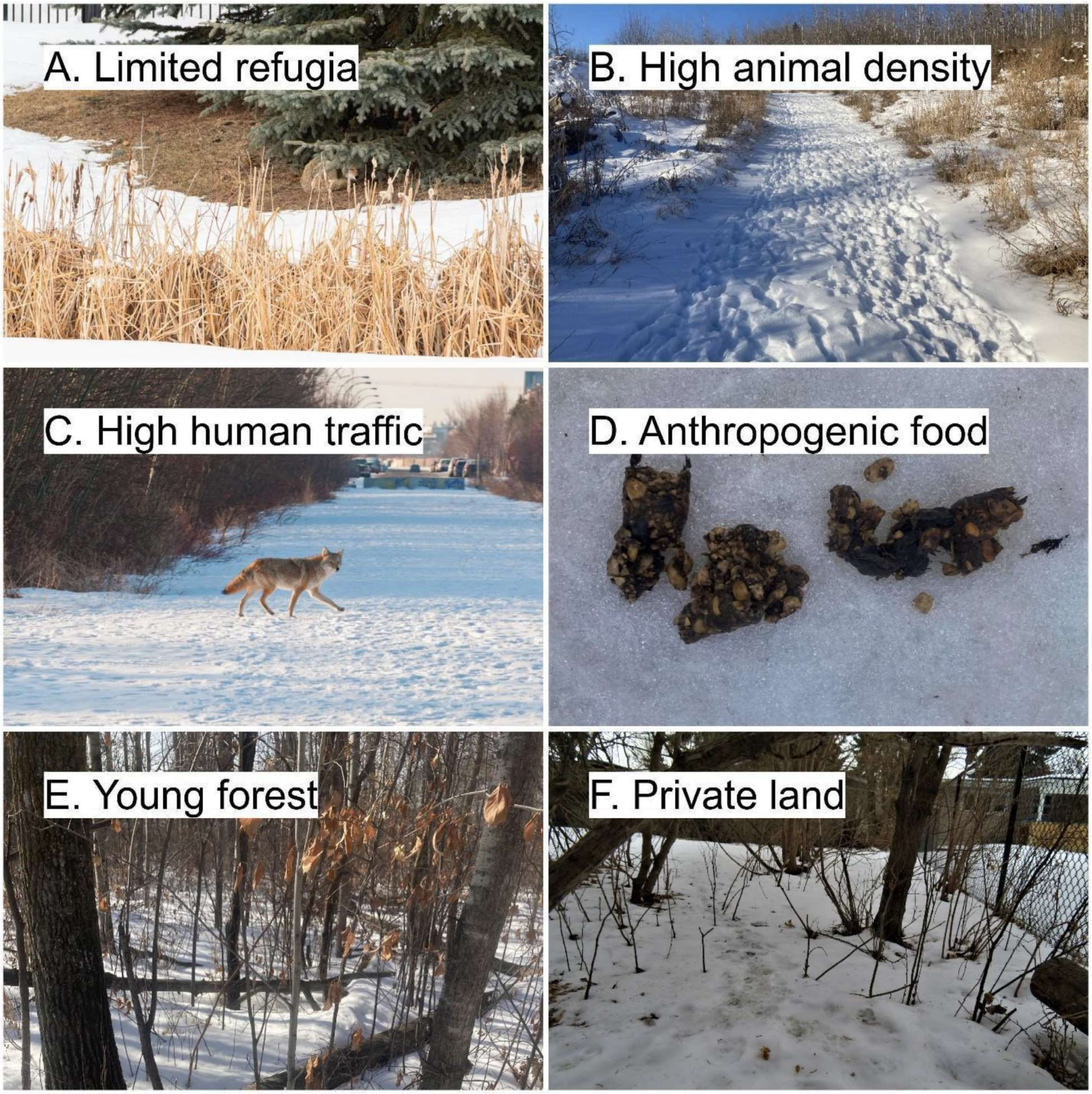

Figure 1. Examples of key challenges associated with trailing in urban areas, Edmonton, Canada, 2020 – 2022. (A) Limited refugia in urban environments means that animals flushed from beds may flee into developed areas (photo credit: Dale Brochu). (B) High animal density makes following the tracks of individual animals difficult. (C) High human traffic deteriorates or removes substrate; here, a coyote travels across snow that has been trampled by people and pets (photo credit: Dale Brochu). (D) When animals eat anthropogenic foods, their scats rarely exhibit typical morphology, such as this coyote scat containing peanuts. (E) Dense vegetation associated with young forest can be challenging and loud to travel through. (F) This trail shows where coyotes left a public green space and entered private land—a common end to trails in urban environments.

Figure 2. A range of coyote scats from Edmonton, Canada, 2020 – 2022, with dominant content including (A) fruit, (B), unknown anthropogenic material, (C) birdseed, and (D) natural prey (deer).

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How Expert Tracking Knowledge Contributes to Wildlife Conservation

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Abstract
WildTrack is a 501(c)3 non-profit founded in 2011 and focusing on non-invasive and community-based wildlife conservation. Our mission is to protect endangered species using a unique synergy of ancient Traditional Ecological Knowledge (TEK), and modern cutting-edge data analytics. We analyze a greatly underutilised data modality–animal tracks–to make informed wildlife conservation decisions on species numbers and distribution. Combined with tracks, our footprint identification technology (FIT) uses two analytical techniques: morphometrics, and artificial intelligence. Together these allow us to decode tracks to the species, individual, sex and age-class levels. These data can then inform on every aspect of conservation biology and strategy, from reducing human:wildlife conflict, to understanding species ecology/habitat requirements to preventing poaching.