GNSS-Based Animal Tracking: An Indirect Approach

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ABSTRACT

Global Navigation Satellite System (GNSS) technology has revolutionised the way 3-dimensional positions are determined on and above the surface of the Earth. Over the last two decades or so, GNSS has evolved into a vital positioning tool for a wide range of applications reliant on spatial data. One such application is the tagging and tracking of animals to better understand animal behaviour and ecology (the study of the relationships that living organisms have with respect to each other and their natural environment). Monitoring animal populations is also necessary for conservation purposes and to limit negative effects on the human population, particularly in an era of human expansion into traditional animal habitats. GNSS technology has allowed significant advances in this field by providing the ability to obtain accurate, regular and frequent estimates of the changing distributions of many rare animal species. However, employing conventional GNSS-based animal tracking methods to study species that spend most of their time in treetops is extremely difficult because the tree canopy regularly causes extended periods of complete GNSS signal loss. This paper proposes an indirect GNSS-based approach for the tracking of tree-dwelling animals. This involves tracking the prey rather than the predator in order to map the animal population in a particular area. Using a case study on drop bears, it is shown that this method can be used to effectively estimate the number of animals present in the area and provide valuable insights into its hunting behaviour.

KEYWORDS: *Animal tracking, ecology, drop bears, GNSS.*

1 INTRODUCTION

The advent of Global Navigation Satellite System (GNSS) technology has revolutionised the way 3-dimensional positions are determined on and above the Earth's surface. GNSS-based positioning has become a vital tool for a wide range of applications in areas such as surveying, mapping and asset management, precision agriculture, engineering and construction, airborne imaging and sensors, and utilities management. A lesser known application that has benefited immensely from the introduction of GNSS technology is animal tracking.

Australia is home to many unique animals, particularly monotremes (i.e. echidna and platypus) and marsupials such as the kangaroo, wallaby, koala, possum, wombat, drop bear and Tasmanian devil. Monitoring these animal populations is important to ensure their conservation and to limit negative effects on the human population (e.g. in the tourism and agricultural sector), particularly in an era of ever-increasing human expansion into traditional animal habitats. Several species, such as the Tasmanian devil, are currently declining, and others, such as the drop bear, are rarely seen. At present, relatively little is known about several indigenous species whose status may be threatened.

Animal tagging and tracking, i.e. the monitoring and recording of the animal's sequential positions, has been used for about 50 years to better understand animal behaviour and ecology (the study of the relationships that living organisms have with respect to each other and their natural environment). Initially, animal tracking relied on VHF (very high frequency) radio technology. Disadvantages of this approach include the requirement of receivers being close enough to the animals to triangulate animal positions and the low temporal resolution of position fixes.

The use of GNSS technology has been responsible for significant advances in this field by providing the ability to obtain accurate, regular and frequent estimates of the changing distributions of many rare species of animals (Tomkiewicz et al., 2010). At first, only large vertebrates such as elephants (Douglas-Hamilton, 1998) and bears (Schwartz and Arthur, 1999) were able to be tracked due to the considerable sensor size and the reliance on rather large, heavy battery packs. Technology improvements and the miniaturisation of equipment allowed the tracking of much smaller animals, including possums (Dennis et al., 2010) and pigeons (Steiner et al., 2000). In all these cases, the GNSS sensor is directly attached to the animal of interest. This makes studying species that spend most of their time in treetops extremely difficult because the tree canopy regularly causes extended periods of complete GNSS signal loss.

This paper addresses these shortcomings by proposing an indirect GNSS-based method for the tracking of tree-dwelling animals. Rather than tracking the animals themselves, the prey is tracked in order to infer the location and size of the population. Using a case study, it is shown that this approach can be used to effectively estimate the number of drop bears in a given area and obtain valuable insights into the animal's hunting behaviour.

2 DROP BEARS

The drop bear (*Thylarctos plummetus*) is an arboreal (i.e. tree-dwelling), predatory marsupial that closely resembles the koala (*Phascolarctos cinereus*) and is therefore difficult to spot. Colloquially, it is often referred to as the carnivorous 'evil twin' of the koala because it is a vicious creature sharing a very similar habitat. Based on megafauna bones discovered in Aboriginal middens, it is believed that the two present species evolved from a single ancestor during the late Holocene. Theories that its dropping skills follow from genetic similarities with sugar gliders remain empirically untested.

The drop bear is a strongly built animal with powerful forearms and claws for climbing and holding on to prey. In stark contrast to the very similar looking but smaller koala, it has large canine teeth that are used very effectively as biting tools. The drop bear generally hunts during the day by ambushing ground-dwelling animals from above, skilfully latching onto the victim's neck to kill its prey. Quietly waiting in a tree for several hours, it closely resembles a sleeping koala. Once prey is within striking range, the drop bear will drop several metres out of the tree to pounce on top of the unsuspecting victim (Figure 1). The initial impact generally stuns the prey, allowing it to be bitten on the neck and quickly subdued. The examination of kill sites and scats indicates that medium to large species of mammal make up most of the animal's diet (Hosking, 2012). Often, the prey is considerably larger than the drop bear itself. A nocturnal variation of the species (*Thylarctos plummetus vampirus*) has resorted to draining the prey of its blood rather than feasting on its flesh (Lestat, 2010).

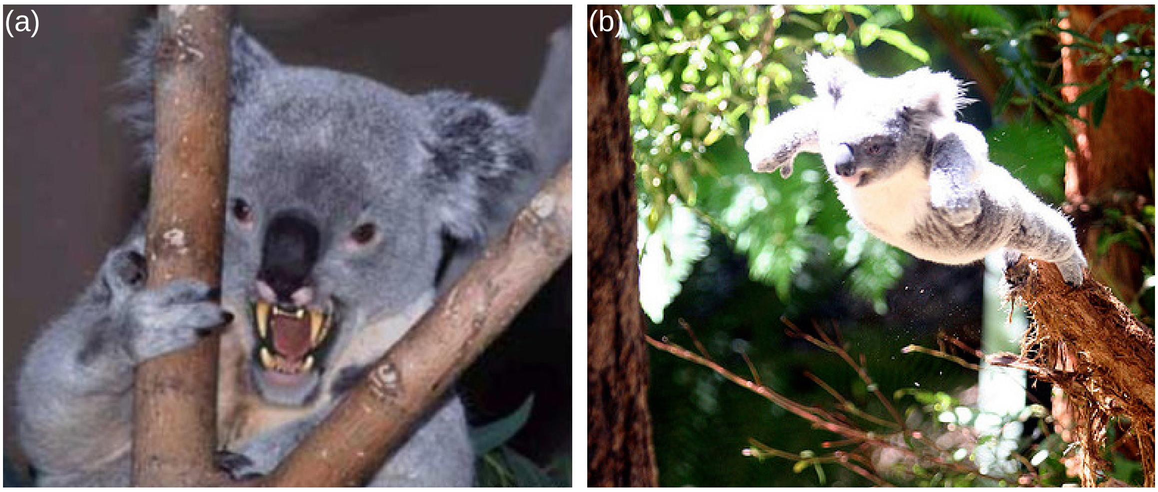

Figure 1: Drop bear (a) in its habitat and (b) attacking prey.

The drop bear is mainly found in coastal regions of eastern and southern Australia, stretching from the Cape York Peninsula to Tasmania. Populations also extend for considerable distances inland in regions with enough moisture to support suitable woodlands not limited to eucalypts. Woodland is crucial since drop bears are not easily able to drop from spinifex bushes and desert plants. It should also be noted that fewer victims in more arid environments reduce the ability to work downwards through the food chain and thus considerably lower survival rates. Reports of periodic attacks on opal miners in Coober Pedy may be questionable and related to excessive consumption of cooling amber fluids in dry areas.

The distribution of drop bears across Australia is quantified by the National Drop Bear Index (NDBI), which indicates the average population density per square kilometre (Figure 2). Aboriginal dreamtime legends suggest that the drop bear was once much more widespread, hence the need for contemporary conservation.

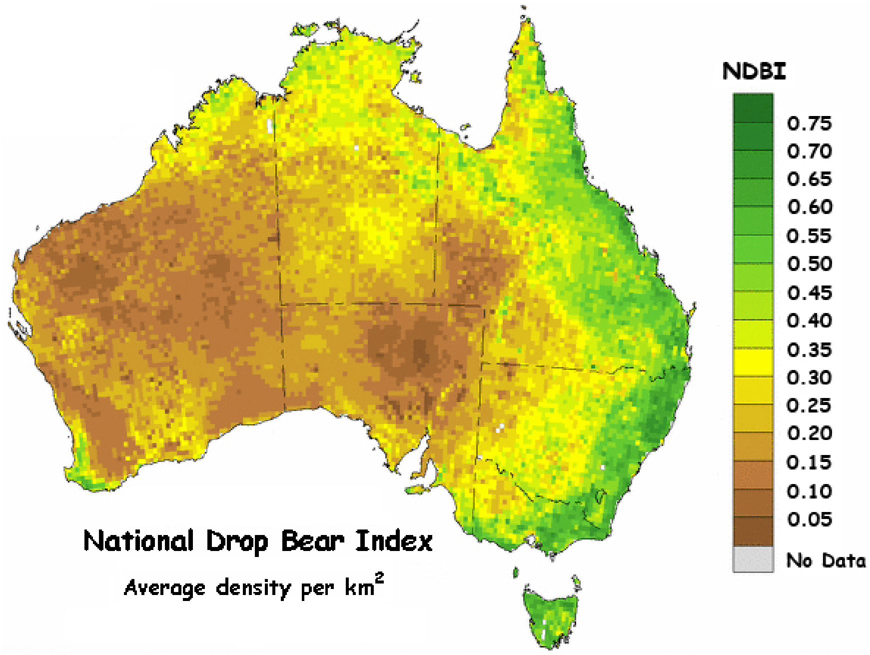

Figure 2: Distribution of drop bears in Australia, quantified by the National Drop Bear Index (NDBI).

Unlike other peculiar Australian animals such as the bunyip and the hoop snake, which are rarely encountered in even thinly populated areas, drop bears pose a considerable risk to unsuspecting bushwalkers, particularly tourists, because they closely resemble the koala. While the Australian government has been accused of orchestrating a conspiracy to cover up the existence of drop bears in order to protect the tourist industry (Langly et al., 1999), these claims have never been substantiated.

Drop bears do not specifically target human beings, but there have been several cases where humans have fallen victim to drop bear attacks, resulting in serious lacerations and even death (Home and Away, 2011). Disappearances which may (or may not) be attributed to drop bears have occurred frequently across Australia (e.g. Holt, 1967; Hussey, 1989; Mulder and Scully, 2000).

Several methods have been proposed to protect humans from drop bear attacks, although their effectiveness often remains scientifically inconclusive (e.g. Skywalker, 2008; Janssen, 2011). These methods include wearing forks in the hair, spreading vegemite or toothpaste behind the ears or under the armpits, urinating on oneself, and avoiding talking in a foreign language or an accent other than Australian.

Other studies have indicated that by-products of the interaction between chemicals found in vegemite and those found in human sweat repel drop bears (Honeydew, 2003). Most Australians and immigrants who have lived in Australia for long periods of time tend to eat vegemite consistently (usually at least once a day), so exuding these chemicals through their skin permanently, and are thus protected. Visitors, on the other hand, do not have this ‘natural’ protection and are therefore advised to apply a liberal amount of vegemite to the skin, the most suitable area being just behind and towards the top of the ear because this area is prone to sweating and closest to the top of the head.

While it is recognised that more research is required, there is unmistakable evidence that tourists are much more likely to be attacked by drop bears than Australians. Genetic analyses suggest that this may be related to the Australian ‘mateship’ trait, which extends to animals unique to Australia (Crikey and Beauty, 2008). Furthermore, it has been shown that drop bears can detect foreign languages and are prone to target the origin of such sounds, but using the Aussie lingo may fool the average drop bear (Stewart, 2005). This indicates important and unusual parallels with the equally rare invasive alien species, the Bundy bear, which similarly favours arboreal habitats and preys on tourists, especially young female blonde foreigners. However, drop bear attacks on humans are rare, mainly because Australians are familiar with drop bear ecology, tourists are deliberately diverted, and reality TV survivor series are usually undertaken elsewhere.

Investigating the effectiveness of several methods of protection against drop bear attacks has shown that the best protection is achieved by wearing a motorcycle helmet when bushwalking in drop bear territory, although this may be impractical in tropical regions (Skywalker, 2008). An accomplished method of determining whether a drop bear may be lurking in the flora canopy is to lie down beneath a tree and spit upwards. If a drop bear is sleeping above, it will most likely wake up and spit back (Young et al., 1981). However, this approach includes some risk, and the consequences can be devastating if drop bears are on the hunt for prey or in the middle of the mating season. Bushwalkers are advised to exercise caution in areas frequented by drop bears, hence the value of the present research.

3 INDIRECT GNSS-BASED ANIMAL TRACKING

Monitoring drop bears is essential to ensure that a sustainable animal population is maintained, while limiting the possibility of attacks on humans. Employing conventional GNSS-based animal tracking methods (e.g. Dennis et al., 2010; Tomkiewicz et al., 2010) on drop bears or other tree-dwelling animals is extremely difficult because the dense tree canopy often results in extended periods of complete GNSS signal loss. Due to the viciousness of the drop bear (even under sedation), there is a considerable risk of injury when the sensor is attached. In addition, the GNSS sensor is prone to severe damage and loss during attacks on prey and due to the animal's habit of rubbing its body against tree branches. This severely reduces the availability of meaningful tracking data and substantially increases the cost of drop bear tracking.

In order to avoid these disadvantages, an indirect GNSS-based approach is proposed. This indirect method involves tracking the prey rather than the predator, thus pinpointing the location and timing of drop bear attacks in order to map the animal population in a particular area. Drop bears are known to be very territorial and generally do not stray far from a relatively small number of trees, located in close proximity, that are used as hunting ground. The location of attacks therefore provides a good indication of where a drop bear resides.

4 CASE STUDY

A case study is used to demonstrate the effectiveness of the proposed indirect GNSS-based animal tracking method. The study area is located in the northern part of Morton National Park, about 120 km southwest of Sydney. The indirect tracking approach was used to estimate the number of drop bears inhabiting this area.

Several research assistants (mainly thrill-seeking international students in dire need of financial support) were equipped with GNSS sensors to track their position during bushwalks off the beaten track. The GNSS sensors utilised the differential positioning technique to provide high-quality real-time positioning solutions relative to a Continuously Operating Reference Station (CORS) nearby. Heavy-duty bike helmets and neck protectors were worn by all data gatherers to guard against potential injuries.

The field work was undertaken on seven consecutive days starting on 1 April 2012. At times, dense tree cover caused some tracking problems and subsequent data gaps. However, due to the application of the differential positioning technique and the availability of the full GPS and GLONASS satellite constellations, coordinate solutions along the paths taken by the data gatherers were generally accurate at the decimetre level or better. This is a significant improvement over conventional GNSS-based animal tracking techniques which routinely provide positions with an accuracy of several metres.

4.1 Location and Size of the Population

The GNSS trajectories of the bushwalkers were used to determine the location (and timing) of drop bear attacks. An example of two typical tracks culminating in an attack is shown in Figure 3a, while a map illustrating the spatial distribution of all drop bear attacks observed is shown in Figure 3b. It can clearly be seen that the attacks appear in distinct clusters, indicating that six drop bears were involved and leading to the conclusion that at least six drop bears inhabit the study area. The timing of the attacks (data not shown) supports this result.

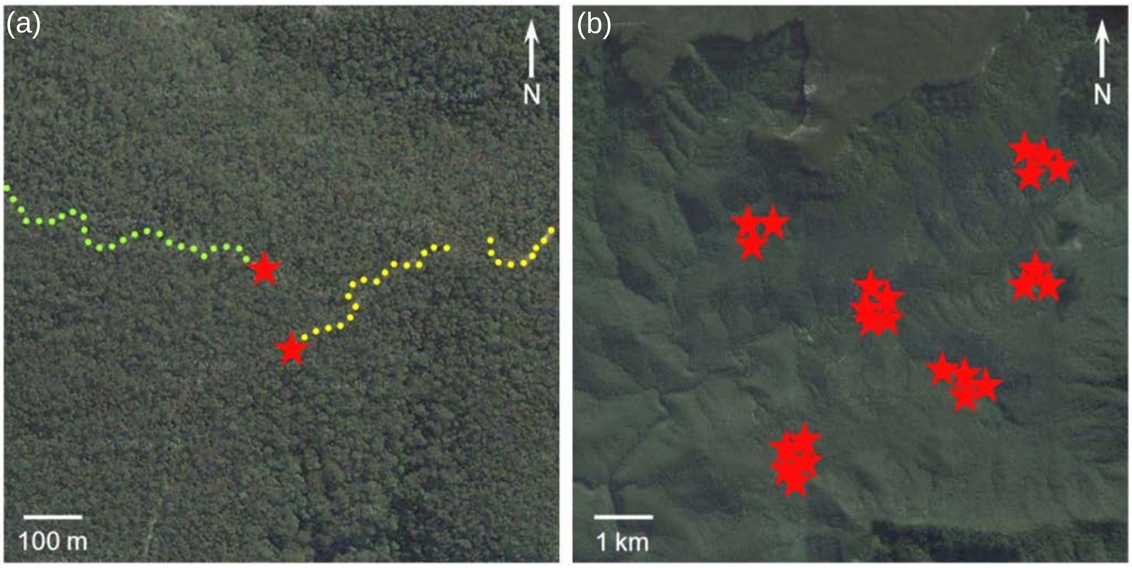

Figure 3: (a) Example of two GNSS tracks ending with a drop bear attack (denoted by a star), and (b) summary of all drop bear attacks observed.

An examination of kill sites and scats in the study area was conducted a month before and after the GNSS field work was carried out. This provided an independent method of estimating the number of resident drop bears and confirmed the findings obtained using the indirect GNSS-based animal tracking method.

4.2 Hunting Behaviour

In an additional investigation, pairs of data gatherers bushwalked along the same path in order to examine whether foreigners were more prone to drop bear attacks than locals. In the first scenario, an Australian was followed at a distance of about 50-100 metres by an international research assistant. In the second scenario, the two data gatherers would swap positions.

While the relatively small data sample collected precluded rigorous scientific analysis, some general comments can be made. In both scenarios, Australians were far less successful in being ‘dropped on’ than foreigners. Only 10% of Australians were targeted in the event of a drop bear attack. It was later discovered that those Australians were not fond of vegemite, lending further weight to Honeydew’s (2003) incisive study. The results also indicate that drop bears do not necessarily target the last person walking in a line. However, more research into the behaviour of drop bears is required in order to confirm these findings, which may reflect seasonality and the presence of alternative food sources.

It should be noted that no animals were harmed during this case study. Likewise, none of the bushwalkers were injured, with the exception of occasional bruising and a few minor lacerations that were graciously endured in the name of science.

5 CONCLUDING REMARKS

This study has presented an indirect approach for tracking tree-dwelling animals using GNSS technology. Rather than attaching sensors to the animals themselves, the prey is tracked in order to map the location and size of the population. Using a case study focused on drop bears, it was shown that this method is effective in both determining the number of animals present in the study area and revealing their particular nutritional targeting preferences. Analysis of the drop bear's hunting behaviour confirmed that foreigners are much more likely to be attacked than Australians. Bushwalkers should be vigilant when hiking along less frequented paths in Australia and take precautions in areas known to be inhabited by drop bears, where conservation practices can now be enhanced.

This bush-path breaking research has begun to provide a much better understanding of the ecology of the drop bear (Janssen, 2012). Extending this research into other seasons and field sites would further enhance our understanding of drop bear behaviour and allow a more thorough exploration of the suggested parallels to Bundy bears.

While GNSS positioning quality was generally at a sufficiently high level, occasional data gaps were encountered due to dense tree canopy (cf. Figure 3a). Following the deployment of additional satellite constellations currently under development (e.g. the European Union's Galileo and China's Beidou), a much larger number of GNSS satellites and frequencies will be available in the near future. This is expected to significantly enhance tracking performance, particularly in Australia which will be a 'hotspot' for global and regional satellite systems (Rizos et al., 2010). Additional benefits could be gained by combining the GNSS sensor with an Inertial Navigation System (INS) to bridge anticipated periods of GNSS signal loss in the forest (Soloviev et al., 2012).

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