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Research Note

Application of low-power wide-area network GPS to koala monitoring

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Abstract. We evaluated long range antennae and associated solar-powered global positioning system (GPS) ear tags designed for use with domestic cattle, as a novel system for monitoring ranging behaviour of the koala (*Phascolarctos cinereus*). The mean location error of our GPS tags was 33.9 m (s.e. = 0.46). The tags were relatively light (30 g), reported eight locations per day when attached to koala radio-collars and had an operating life that exceeded our study period (8 months). Deployed as a stand-alone, solar powered, remote system, this technology can provide a viable option for wildlife tracking projects.

Keywords: fix success, location data, LoRaWAN, movement patterns, solar-power, spatial ecology.

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Introduction

Global positioning system (GPS) technology is widely used to acquire location data for spatial analysis in wildlife research (Tomkiewicz *et al.* 2010). Hand-held GPS units have been replaced by small tags carried by the subject species, reducing observer-created artefacts that can affect behavioural studies and resulting in location data collected at predefined intervals, providing more locations than traditional VHF methods (Bandeira de Melo *et al.* 2007; Read *et al.* 2007; Mandel *et al.* 2008; Frair *et al.* 2010).

We have previously used purpose-built store-on-board wildlife tracking collars (Ellis *et al.* 2011; Robbins *et al.* 2019*a*, 2019*b*) and repurposed commercial GPS tags to attach to VHF tracking collars (Ellis *et al.* 2016) to conduct such studies on koalas. Here we investigated the use of a low-power long-range (LoRa) system, to collect and transmit location data from koalas, in urban and rural settings. Our aim was to test the functionality of this technology to collect spatial data for koalas. If the extended battery life and low weight of the GPS tags, paired with the standalone field base stations that complete the systems, proved suitable for wildlife research, high quality data at relatively low cost could be within reach of many research teams.

Materials and methods

Study sites

In 2013 we established and began monitoring a translocated population of koalas at 'Tandora' (–25.454054°, 152.803770°), a privately owned cattle station located 20 km northeast of Maryborough, Queensland, from where koalas were extirpated over 100 years ago (Miller 2018; FitzGibbon *et al.* 2020). In addition, we monitored the koala population that utilises the Belmont Hills Reserve (–27.509614°, 153.120226°), a dedicated green space in the Brisbane suburb of Carindale in southeast Queensland.

Data collection

The low-power wide-area network (LPWAN) system we used is accessed by the company 'Moovement'™ (https://moovement.com.au). It relies on low power, LoRa wireless transmission over large distances (5–40 km, depending on topography) (Mekki *et al.* 2018). The tags are small (30 g, 45 × 55 × 10 mm, Fig. 1*a*) solar-powered polycarbonate-enclosed cattle ear tags, which communicate with LoRa gateways. Each gateway consists of an antenna attached to a standard wireless router, containing a cellular sim card which communicates with the network server, delivering the data through a user portal (Amazon Quicksight) and mobile phone application ('Moovement BV'). Prior to this study, the ability of the LoRa system to provide biologically useful data had not been reported, although the system is being trialled on American bison (*Bison bison*) (American Prairie Reserve, pers. comm. 2020).

To evaluate GPS accuracy, we deployed two stationary tags at each study site; one in an exposed location, and one placed beneath the canopy to imitate conditions experienced by koalas. These tags were programmed to collect one fix every hour, continuously.

Additional GPS tags, also programmed to transmit a location once every hour, were attached to the collars of nine radio-tracked koalas between April 2020 and December 2020; four at Tandora and five at Belmont Hills. The tags were attached with

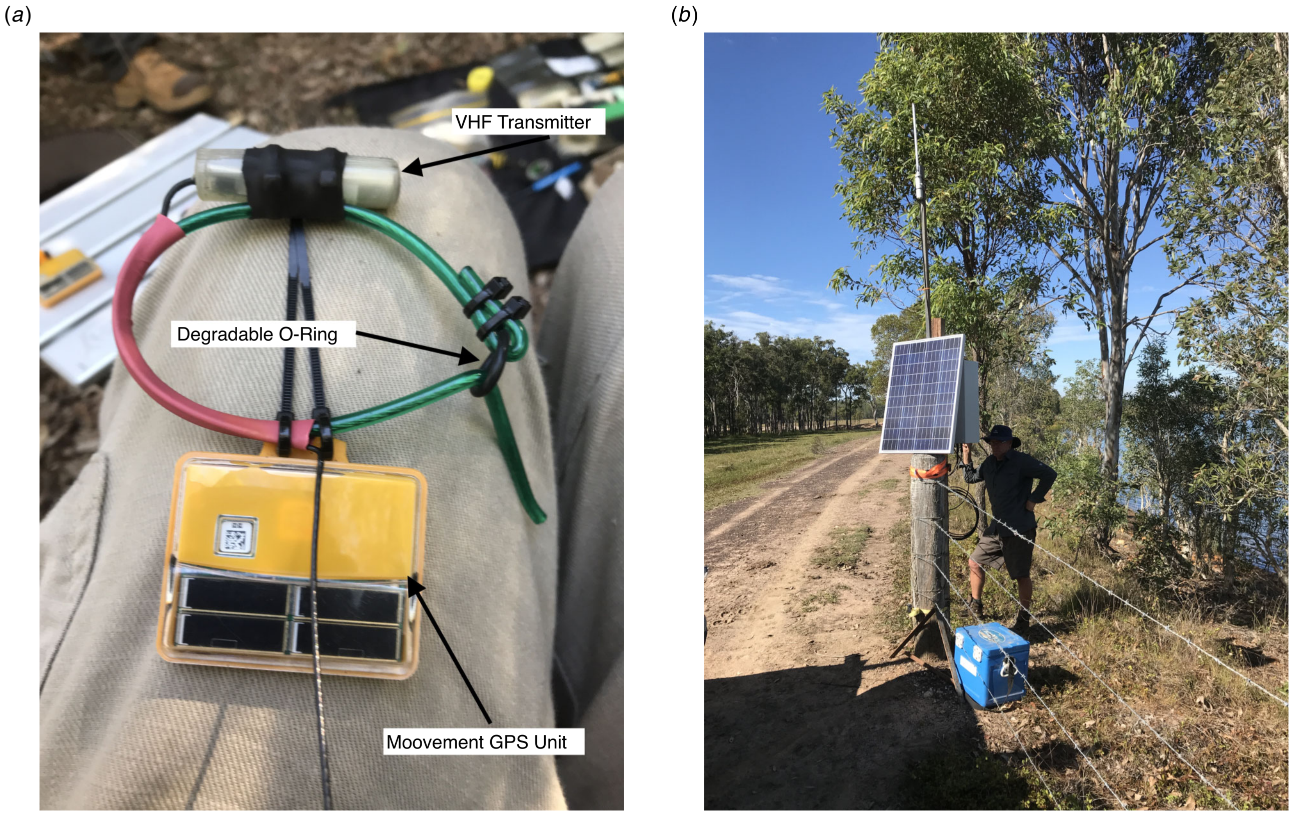

Fig. 1. (*a*) Koala collar in construction, with vhf and Moovement™ tag attached. Rubber o-ring used as flexible and degradable weak link. Lead weight not attached to VHF. (*b*) Autonomous, solar-powered gateway established at Tandora to monitor collared koalas during 2020. Photographs by W. Ellis.

cable ties to a polycore filament collar which simultaneously carried a VHF transmitter (Advanced Telemetry Systems, model A2650, 25 g) and lead weight (acting as a counterbalance 25 g) which dorsally aligned the GPS tag on the koala (Fig. 1*a*). Collars had a built-in rubber o-ring designed to stretch and degrade over time (Ellis *et al.* 2015), to release in the event of collar failure or collar becoming 'snagged' or even in the event of unsuccessful recapture.

At Tandora, we established an autonomous, solar-powered LoRa antenna (Fig. 1*b*); at Belmont, a local resident provided access to mains (240V DC) power enabling the establishment of a mains-powered system. In addition, we powered a LoRa antenna from a second battery system in our research vehicle, providing a mobile data collection platform for use at either site.

Data analysis

We have previously calculated the average location error for Sirtrack GPS tags (Ellis *et al.* 2011, 2016) and for repurposed commercial GPS tags (iGotU; Ellis *et al.* 2015) and undertook a similar analysis here. For each stationary tag, the reported fix quality (fix accuracy value, in metres) of each location was assessed for actual distance from the known location of the tag, to calculate true location accuracy. Distances were calculated as the geodesic distance (the shortest path between two points on the earth at sea level) between the reported fix and true location, using the haversine formula.

We then plotted the reported fix accuracy values for each fix of the stationary tags against their corresponding calculated error, to visualise the relationship between these measures and to detect threshold fix accuracy values suitable for koala range and movement analysis. Fix success rate was calculated from the ratio of attempted and successful fixes for each tag, as a measure of likely output (both for stationary and on-animal tags). To assess the cost-effectiveness of the LoRa system, cost per fix was calculated from equipment costs and total number of received fixes for both stationary tags and deployed koala tags, to complement the study of Matthews *et al.* (2013).

Ethical statement

Study methods were approved by the University of Queensland Office of Research Ethics (SAFS/528/18) and conducted under Scientific Purposes Permit WISP16162915.

Results

All four stationary GPS tags transmitted location data for the entire data collection period between April and November 2020, receiving 9527 of a possible 20 712 (46%) location reports (one tag was re-deployed for use with a koala collar in September). Fix success rate of the individual tags ranged from 14 to 60%, with an average of 10.8 fixes per tag, per day and an average error across all stationary tags of 33.9 m (s.e. = 0.46). There was

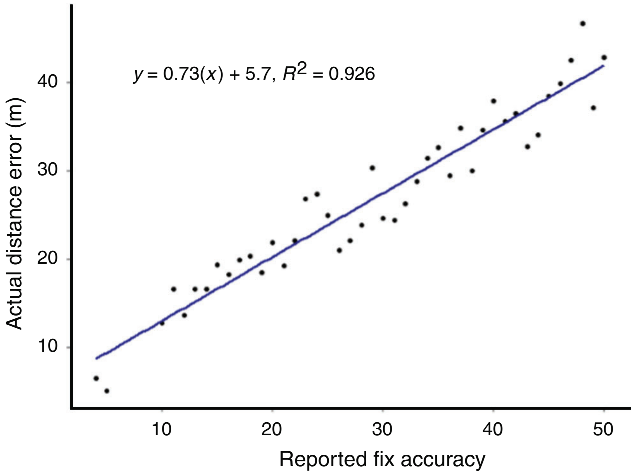

Fig. 2. Calculated fix accuracy (*y* axis) and reported location error (*x* axis) for stationary tags deployed at Tandora and Belmont Hills, Queensland. Only data for reported accuracy below 50 m are included.

a positive linear relationship between fix accuracy value and calculated location error for stationary tags at fix accuracy values of 50 or less (Fig. 2, $R^2 = 0.926$), indicating that reported fix accuracy values in this range closely approximated actual fix error. Average error for locations with a fix accuracy value less than 50 m was 19.3 m (s.e. = 1.34).

All tags deployed on koalas supplied location data, however two tags supplied fewer than (on average) one fix per day, two koalas were only monitored for part of the study (added after the study began and hence not included in analyses) and one koala moved out of range of the gateway during the study. The average daily fix rate of the remaining five tags was 8.6 fixes per day, with a range of less than 1 to more than 13 fixes per day. The mean reported fix accuracy of all deployed tags was 46.8 m (s.e. = 0.47; corresponding to 39.9 m, Fig. 2). All data are available in ZoaTrack (Dwyer *et al.* 2015).

The total cost of equipment for the two LoRa systems including the fixed costs of standalone gateways, data portal access and tags (30) was AU$11 709. From 10 958 successful fixes across four stationary tags and seven koalas between April and September, the mean calculated cost per fix (excluding labour) was AU$0.93. The cost per tag is very low (AU$60 per tag) so cost per fix should be lower for longer (or larger) projects. Deployed tags have continued to report locations for more than 12 months and their operating life expectancy is unknown.

Discussion

The aim of this study was to assess the potential of LoRa systems to inexpensively deliver high quality data to wildlife researchers. For Queensland koalas, a medium sized (4–10 kg adult) species that spends most of its life in trees, this system can deliver reliable, near real time indications of location for long term (>12 months) studies.

Overall average location error of the tags (33.9 m) fell within the reported average daily movement distance of the koala in central Queensland (53.6–63.3 m; Ellis *et al.* 2009) and slightly above that reported in southeast Queensland (22.4 m; Barth *et al.* 2020). Hence, we recommend to only use locations with fix accuracy values within the daily average movement distance of the subject species. For animals moving smaller distances, for which location fix inaccuracy would be greater than actual movement, the technology may be unsuitable.

Removing all reported locations for which reported fix accuracy is greater than a value of 50 m maintains 70% of the original fixes and is likely to retain more than one fix per day (our mean fix rate was approximately 9 per koala, per day) resulting in increased average fix accuracy. Across the deployed tags (on koalas), 15–18% of fixes (or approximately one per day) reported accuracy better than 30 m. Careful data filtering could therefore result in few, high quality fixes per day (per koala), allowing detailed range analysis comparable to VHF and some other GPS tracking data to be undertaken. Hence complete, longer-term range analysis, investigating resource selection, patterns of movement and even tree selection similar to previous studies in Queensland, (Davies *et al.* 2013) and New South Wales (Crowther *et al.* 2014) should be possible using this technology.

Fix success rate varied between koala deployments, which is consistent with other reports for GPS deployments (Frair *et al.* 2010); in our study, the overall average fix success rate was negatively impacted by a single koala with a fix success rate of 3%, due to the collar rotating so that the GPS sky view was obscured. Our overall fix success rate was just under half of all acquisition attempts (46% stationary, 17–50% deployed); reprograming tags to collect more locations during periods of animal activity, and less during the daytime (when koalas are invariably under canopy and relatively sedentary), could result in a more useful data set to understand koala activity.

Setting aside data for koalas that left the study site or for which tag failure could be attributed to 'operator error' (failure to properly attach and counterbalance the tag), approximately ten fixes per day, of which almost 70% will be more accurate than 50 m, can be expected using the Moovement system with koalas. Many studies of spatial dynamics of koalas have relied on a single daily location (Ellis *et al.* 1990; Lassau *et al.* 2008; Ellis *et al.* 2009; de Oliveira *et al.* 2014; Goldingay and Dobner 2014; Matthews *et al.* 2016; Barth *et al.* 2020) and the LoRa system we trialled can produce data of similar quality and quantity. The current tags are light and small and were easily modified for attachment to koala collars. They could similarly be used to monitor other species of sufficient body size (e.g. possums, macropods). At present, the system does not incorporate features such as accelerometry to detect illness or death, as can be done with the Lx system (Robbins *et al.* 2019*b*). Fossorial and strictly nocturnal species may be less suitable for this system, given the reliance of the tags on solar recharging, but the portable multi-platform interface and simple setup of this system are key advantages over current alternatives.

Conflict of interest

The authors declare no conflicts of interest.

Declaration of funding

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