SHORT COMMUNICATION

Cost comparison between GPS- and VHF-based telemetry: case study of feral cats *Felis catus* in New Zealand

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Abstract: Improvements in technology now make it possible to track animals of cat size using Global Positioning System (GPS)-telemetry. GPS technology has important advantages over traditional Very High Frequency (VHF)-radio tracking, but does incur higher per-tag costs. Budget is a limiting factor in experimental research; thus, an evaluation of the costs associated with both technologies according to the targets of a project should be undertaken before making any final decisions on the purchase of units and final experimental design. We simulated and compared the relative costs associated with the use of GPS and VHF telemetry applied to the study of the spatial ecology of feral cats (*Felis catus*) in the Tasman Valley (South Island, New Zealand) as a test case. We assessed different project durations and location acquisition rates. Cost analysis revealed that GPS-telemetry is the less expensive method to quantify the spatial ecology of feral cats when long-term (>1-year duration) projects and/or high acquisition rates (>1 location/day) are required.

Keywords: animal movements; project budget; spatial ecology; Tasman Valley

Introduction

Wildlife tracking systems based on satellites have been applied as an alternative to the traditional VHF radio-tracking technologies. Since the establishment of the Navstar satellite constellation, Global Positioning System (GPS) technology has been used to study animal movements, with the range of applications increasing with the development of lighter and smaller receiver units. Key advantages of using GPS over traditional VHF-based tracking include the ability to collect data in remote locations, over large areas and long periods of time, in all-time/all-weather conditions without the need to maintain a costly team in the field, and with the potential to increase sampling frequency to derive conclusions about fine-scale behaviour patterns and resource use in space and time (Millspaugh & Marzluff 2001).

To date, attempts to evaluate broad- and medium-scale habitat use by introduced mammalian predators in New Zealand have relied on VHF radio-telemetry (e.g. Murphy & Dowding 1995; Ragg & Moller 2000). In part, this is because of the greater unit costs of GPS tags (NZ$3,000+ versus NZ$300 for a VHF tag). However, unit cost is only one component of resourcing a spatial ecology project and the de facto use of the cheaper VHF tags may ignore or underestimate the much greater costs involved in obtaining often imprecise and infrequent animal location estimates using VHF telemetry, in particular the human resource costs.

Typical project costs include the purchase of equipment, expenses for field personnel, salaries, and costs for transportation. These costs will depend on the study design, including the number of animals to track, frequency of locations, and the specific challenges involved in data collection in the case of VHF radio-tracking. According to Pollock (1987), even if the optimal study design is too costly to achieve, the researcher can proceed, understanding the limitations, with some modified design in an attempt to obtain any valuable information. Hence, an accurate evaluation of the costs associated with the alternative technologies available is needed to ensure the best possible results are achieved within a given budget.

We aim here to compare the relative costs of running a project based on traditional VHF radio-tracking versus the application of GPS tags, by means of different simulations of project duration and location acquisition rates. We based our simulations on a recent study of the spatial ecology of feral cats (*Felis catus* L.) in the Tasman Valley, South Island, New Zealand (Recio et al. 2010).

Materials and methods

Sample size of locations per animal is principally constrained by battery life in GPS telemetry and by the time required to collect each position in VHF radio-tracking (Kenward 2001). We compared the costs associated with telemetry projects based on traditional VHF and GPS techniques, under the same fix frequencies and project duration combinations. Standard fix rates were set at one location per hour, one every 6 hours, one per day, and one every 2 days (i.e. 1-h, 6-h, 24-h, 48-h fix rates). Project duration was set at 30, 90, 180, 270 or 365 days, which are biologically relevant periods to study space use and activity patterns of cats. The number of collars was equal to the sample size of animals to be tagged. According to manufacturer specifications (Sirtrack pers. comm.) the cost in 2009 of a GPS collar was on average at least seven times the cost of traditional VHF equipment, with GPS batteries lasting for 53 days at 1-h, 219 days at 6-h, 412 days at 24-h and 483 days at 48-h fix rates.

We defined 'trapping campaign' as the full cycle from the capture of N individuals to be fitted with a collar, to their later recapture. In our feral cat project (Recio et al. 2010), we used GPS data-logger collars (Sirtrack, Havelock North, NZ, http://www.sirtrack.com) to tag individuals. The total weight of each collar as fitted was 125 g. This weight meant it was possible to tag only adult feral cats with a body mass over 2.5 kg in order to keep unit weight less than the recommended 5% of body mass (Cochran 1969; American Society of Mammalogists 1998). In order to minimise unit weight, no drop-off system was mounted in the collar; instead cats were recaptured, using two feral-cat-locator dogs specifically trained by the New Zealand Department of Conservation.

For our calculations, we selected a sample size of N = 14 individuals (Table 1). We estimated, according to our experience, that the number of cage traps required to capture N feral cats is three times sample size (3N) and that the trap success associated with this number of traps deployed is one cat per day, so total days of trap deployment is equal to sample size (N). Cage-trapping cat acquisition costs would be equal for both VHF and GPS projects. We determined that two operators are required for trapping. Hence total effort and cost of a single trapping campaign were assumed to be the same for both telemetry modalities. However, GPS devices are constrained by battery life duration dependent on the fix rate configuration and the length of the project. Therefore, additional trapping would be required for some of the combinations of both variables. The cost of one vehicle was added for the trapping period based on the per-kilometre costs for the Department of Conservation to lease an all-terrain or 4WD vehicle (DOC Twizel, pers. comm.) Distance travelled per day was assumed to be that of the trapline, covering the length of the area of study and return. For our simulations we took as reference the length of Tasman Valley, estimated as 20 km.

Effort and costs required to acquire animal location records using VHF telemetry are directly proportional to the sample size of animals (N), and inversely proportional to the available time between fixes. Hence, we assumed as optimal a minimum of one operator recording up to four animals per hour, so several operators are simultaneously required for the shorter fix period of 1 h. Working shifts were assumed, to cope with a 24-h cycle for 1-h and 6-h fix rates. One working shift was suitable for the one location per day and one every 2 days rates. Working shifts applied 7 days a week. Salary costs for the number of operators required for every project configuration were calculated based on the salary rate established by the University of Otago (Dept of Zoology administration, pers. comm.) for entry-level research assistants.

Vehicle cost was also included in each tracking campaign, considering that one vehicle is required per operator at the rates described above. Distances travelled per operator and working shift varied according to the number of locations per hour. In order to achieve a rate of one location per hour (and meet the assumption of one operator obtaining an average of four animal locations every hour), the size of the surveyed area was divided into as many sectors as the number of operators required to obtain the appropriate fix rate. Every operator would travel the distance of the estimated sector once per hour. For the other fix-rate configurations, only one operator per working shift was required to travel the total length of the study area and return.

All the costs per project per modality and configuration were added. We calculated a proportional 'cost rate index' to compare costs of traditional VHF telemetry with GPS telemetry for a given configuration:

Cost rate index = VHF project costs / GPS project costs

Results and discussion

The cost rate index compares the budget requirements of traditional VHF relative to GPS telemetry as a function of project duration and fix frequency. A cost rate index less than 1 indicates lower costs in favour of traditional VHF telemetry, whereas index values greater than 1 indicate lower costs in favour of GPS telemetry. The cost rate indices shown in Fig. 1 show that GPS telemetry becomes more cost effective with an

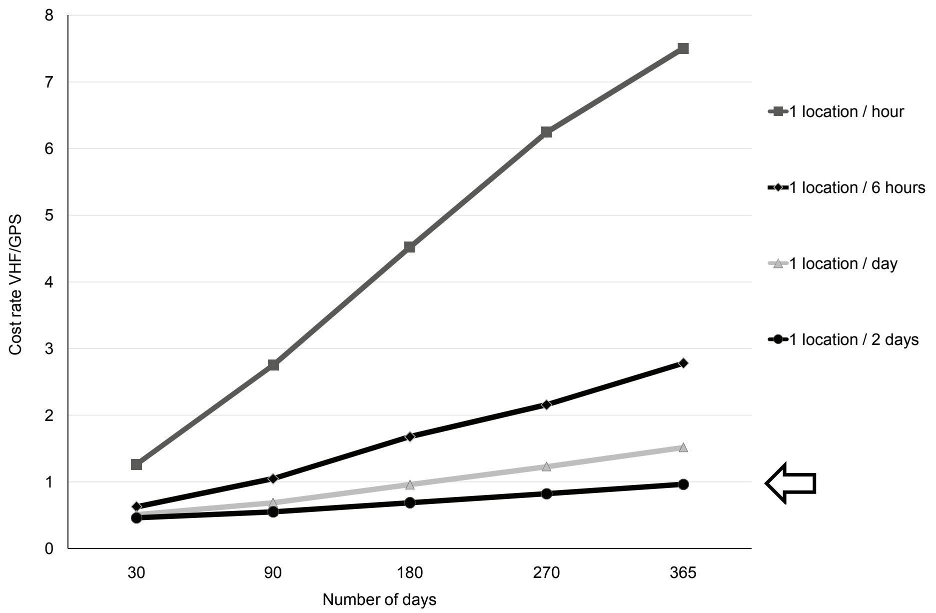

Figure 1. Comparison of costs between VHF radio-tracking projects and GPS telemetry projects using cost rate (cost rate index = VHF project costs / GPS project costs). Estimated costs based on a sample size of 14 animals (N = 14). The arrow indicates the level, cost rate index = 1, above which a GPS telemetry project is more cost effective than a VHF telemetry project.

Table 1. Relative-cost calculations between VHF and GPS projects. We assumed that the per unit cost of a GPS collar is 7 times the cost of VHF, and the number of traps required is 3 times the sample size of animals to trap. Number of trapping campaigns (TC) differ between modalities and depend on collar battery life and location acquisition rate in GPS collars. Collar cost is the main variable that increases the total cost of the GPS project, followed by TC. Total cost per tracking campaign (TCTrck) is the variable that increases the cost in a VHF project.

	VHF (Value)	(Equivalence)	GPS (Value)
Animals tracked			
No. of animals (N)	N	=	N
Collar costs			
Unit cost (UC)	VHF UC	<	7 * VHF UC
Total unit cost	N * VHF UC	<	7 * N * VHF UC
Trapping campaigns			
No. of trapping campaigns (TC)	VHF TC	≤	GPS TC
No. of operators per campaign (Op)	Op	=	Op
Salary per operator/hour (SOp)	SOp	=	SOp
Worked hours/day (Wd)	Wd	=	Wd
No. of days (D)	D	=	D
Total salary/campaign/operator (T1)	SOp * Wd * D	=	SOp * Wd * D
Total salaries/campaign (T2)	Op * T1	=	Op * T1
Total salaries/project (T3)	VHF TC * T2	≤	GPS TC * T2
Cost per trap (Ct)	Ct	=	Ct
No. of traps	3N	=	3N
Total cost traps (T4)	Ct * 3N	=	Ct * 3N
Vehicle cost/km (Vc)	Vc	=	Vc
km/day (Kd)	Kd	=	Kd
Total vehicle cost for trapping per campaign (T5)	D * Vc * Kd	=	D * Vc * Kd
Car cost for trapping/project	VHF TC * T5	≤	GPS TC * T5
Total cost per trapping campaign (T6)	T2 + T5	=	T2 + T5
Total cost trapping per project	[(VHF TC) * T6] + T4	≤	[(GPS TC) * T6] + T4
Tracking campaign			
No. of days (TrD)	TrD	>	-
No. of tracking operators per shift (TrOp)	TrOp		
No. of shifts (Sf)	Sf	>	-
No. of hours per shift (HpS)	HpS	>	-
Salary per operator/hour (SOp)	SOp	>	-
Cost of operators per day	TrOp * Sf * HpS * SOp	>	-
Total salaries operators per campaign (T7)	TrD * (TrOp * Sf * HpS * SOp)	>	
No. of vehicles (V)	V	>	-
Vehicle cost/km (Vc)	Vc	>	-
Km per vehicle and shift (kmVSf)	KmVSf	>	
Cost of vehicles per shift	V * Vc * KmVSf	>	-
Cost of vehicles per day	Sf * (V * Vc * KmVSf)	>	-
Car cost for tracking campaign	TrD * Sf * (V * Vc * KmVSf)	>	-
Total cost tracking campaign (TCTrck)	T7 + TrD * Sf * (V * Vc * KmVSf)	>	-
Total project costs	[N * (VHF UC)] + [((VHF TC) * T6) + T4)] + TCTrck		[7 * N * (VHF UC)] + [((GPS TC) * T6) + T4)]

increase in project duration and/or fix rate. For projects that run longer than one year, GPS telemetry is more cost effective whatever the required fix frequency. Projects requiring high (one location per hour) or low frequency data (one location every 2 days) produced different results. With 1-h fixes, the costs incurred in a traditional telemetry project increased very rapidly over time relative to those of a GPS project. GPS telemetry is more cost effective at this acquisition rate whatever the project duration, with traditional telemetry being between 1.2 and 7 times more expensive. Inversely, for the lowest fix frequency (48-h fixes), traditional telemetry proved to be cheaper than GPS telemetry, both incurring the same costs after a full year project. Fix frequencies of one every 6 h and one per 24 h produce intermediate scenarios, with GPS telemetry becoming less costly than traditional telemetry if the project duration is longer than 90 or 180 days, respectively.

Institutional costs invested by the Department of Conservation in the training and maintenance of feral-cat locator dogs did not add to our estimations. Using locator dogs to recover units as this would obviate the need for collars to have a built-in release system and thus reduce total collar weight. Other initiatives (see Moseby et al. (2009) in

Australia) using GPS collars to track feral cats relied on their status as pest species and hence as targets of poisoned baits, traps or otherwise killed after tagging. Recovery methods will not be a limiting factor in the tagging of small mammals whenever reliable and suitable sized collars equipped with a release system can be developed. Meanwhile, although GPS collars equipped with release systems are the most widely used today, they can be deployed only on species over a certain body-size. Hence, we aimed to make this budget comparison extendable to other species and standard circumstances by not including dog costs as a variable. Moreover, dogs may also be considered a suitable method to recover VHF collars and therefore share with a GPS-based project the same expenditure on dog training and maintenance.

Considering the latest improvements in GPS technology and our analysis of associated costs, we believe GPS telemetry is the most efficient and cost-effective method to study the spatial ecology of feral cats in New Zealand when long-term projects and/or high acquisition rates are required. The simulation method applied in this research can be used for other species of different sizes and also for different areas of study in other countries. However, if the body-size of the focal species is insufficient to cope with the weight of a collar equipped with a release system, it may be necessary to consider alternative methods of recovery, such as the use of trained dogs or intensive recapture trapping efforts. All these recovery methods may increase the budget and must also be evaluated. Variables should also be modelled considering the local costs of salaries, vehicles, accessibility and ease of work in the area of study. High a priori costs of GPS telemetry may be a key driver for the slow uptake of this technology, but this assessment of overall costs demonstrates its value-for-money.

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