An evaluation of two methods for assessing population densities of introduced predators in Southwest Western Australia

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Abstract

A study of introduced predator activity in the jarrah forest of the Upper Warren region of Western Australia found that density estimates cannot be accurately drawn from activity indices on sandpads. Estimates of 0.08-0.14 foxes per km^2 and 0.02-0.20 cats per km^2 were calculated. These estimates are well below those from other sources, due to inherent limitations of sandpad surveys. These are discussed. Motion-sensor cameras, however, may be able to accurately estimate population densities, as their ability to detect animals overall and distinguish between individuals is superior to that of a sandpad. A comparison is made of the cost and time investment necessary between studies involving sandpads and cameras. The relative effectiveness and costs of alternate methods for estimating density in relation to the study area and species are also considered.

Acknowledgments

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1. Introduction

Non-marsupial mammalian predators first arrived in Australia in 1788 (Abbott 2002). At the establishment of the British in Sydney, there are several early reports of cats (*Felis catus*) kept as pets (Abbott 2002). Cats were subsequently introduced to Perth and Albany in the early 1830s, and had established feral populations in the surrounding forests by the mid-1840s (Abbott 2002). Foxes (*Vulpes vulpes*) arrived first in Victoria, successfully introduced for hunting in 1871—around the same time as their natural prey, the European rabbit (Rolls 1969). By 1893, they were already considered a pest in that area, with a bounty being placed on fox heads in three Victorian shires (Rolls 1969). Foxes were first recorded in Western Australia in the early 20th century (again, following the rabbits), and had made it to the Southwest coast by the 1930s, about 100 years after their feline counterparts (Long 1988).

With the arrival of Europeans, native fauna numbers quickly began to decline. Burbidge and McKenzie (1989) compared Western Australian island populations of small mammals on islands with and without disturbance (including fire, housing, mining, introduction of cats, introductions of foxes, etc.), finding that on islands without human disturbance, no mammal within the "critical weight range" (Burbidge and McKenzie 1989) declined or became extinct, whereas on islands containing cats and/or foxes islands and no rock piles for shelter, at least one native mammal declined or went extinct. Kinnear *et al.* (1988) determined that fox predation was the most significant factor hindering the population growth of threatened black-flanked rock wallabies in the wheatbelt region of Western Australia (~200 km east of Perth). Many recent successes in recovery of native WA fauna has been on the heels of large-scale fox-control efforts (Friend 1990, Start *et al*. 1998, Morris *et al*. 2003). Likewise, feral cats have been implicated in species decline through circumstantial and historical evidence (Finlayson 1961, Spencer 1991, Calver and Dell 1998), but it is often difficult to isolate effects of feral cats from those of foxes. Risbey *et al.* (2000), however, displayed the effects of rapid cat population growth (by fox removal) on a small isolated area. They found that trapping success for small mammals dropped by 80% over two years. The Department of Environment, Water, Heritage, and the Arts *Threat Abatement Plan for predation from feral cats* (2008) lists 34 bird, 37 mammal, 7 reptile, and 3 amphibian species as being at risk from cat predation. In a cat- and fox-free enclosure in South Australia, Moseby *et al.* (2009) found that small mammal and reptile populations increased by as much as 15 times over outside populations.

Among the species commonly considered as having suffered at the "hands" of introduced predators is the critically endangered woylie, or brush-tailed bettong (*Bettongia penicillata ogilbyi*). Woylie pre-European settlement distribution is thought to have covered much of the Australian continent, generally in semi-arid scrub or forest habitats (de Tores and Start 2008). Today, its natural range is restricted to three small areas of schlerophyll woodland in Southwest Western Australia: Tutanning Nature Reserve, Dryandra Woodland, and the Perup Nature Reserve and surrounding jarrah (*Eucalyptus marginata*) forests (de Tores and Start 2008).

The population of the woylie has undergone three major changes: an initial major decline from the late-19th century through mid-20th century, a recovery from the mid-1970s through the early 2000s, and a second decline lasting the majority of the first decade of the millennium. The initial major decline may be attributable to fox predation (among other human-related factors), and the 30-year resurgence has been linked to fox-control efforts (Start *et al.* 1998). However, the causes of the most recent woylie decline are not clear. One of the most evident deficiencies of information is the lack of known population densities of foxes and cats in woylie habitat, particularly in its historical stronghold, Perup Nature Reserve. Wayne *et al.* (2011) determined that the minimum population density to solely account for the woylie decline in this region would be 0.5 predators per km^2 assuming one woylie killed per predator per night and no woylie deaths from means other than predation. To understand the role of predators in the most recent woylie decline, it is necessary to determine how close current predator population densities are to that minimum necessary density estimate.

There are several possible methods that can be used for approximating fox and cat populations: DNA capture-mark-recapture, index-manipulation-index, intensive shooting, trapping, and poisoning, spotlighting, sandpad surveying, and sandpad surveying with the addition of motion sensor cameras.

DNA capture-mark-recapture (CMR)—luring animals to a bait station with a sticky pad or barbed wire to catch some hair—is a potentially promising method because it yields an estimate of absolute abundance. However, models associated with CMR techniques assume geographic closure (no random movements into or out of the study area). Boulanger *et al.* (2002) evaluated two methods for carrying out DNA CMR studies on grizzly bears in British Columbia, finding that large grids with widely-spaced bait stations more closely conformed to the geographic closure estimates of their models, but were more likely to miss individual animals within their study area. Likewise, smaller grids accounted for more of the individuals present, but more poorly predicted the movement of bears in and out of the grids. Ideally, grids for animals with potentially low populations densities and large home ranges, like cats (Jones and Coman 1982, Edwards *et al.* 2001) and foxes (Coman *et al.* 1991, Phillips and Catling 1991), would be extensive and intensive. In other words, the grids area should be large and the spacing of the bait points should be tight. However, depending on habitat, this may be difficult given budget and manpower constraints. It has also been noted that detection probability should be calculated for each species to give more accurate results (Forsyth *et al.* 2005).

Index-manipulation-index (IMI) methods have been used previously in Australia to give population estimates of predators. Short and Turner (2005) used spotlighting and poisoning with cyanide as index and manipulation, respectively to estimate feral cat populations at Shark Bay. Their estimate was reasonable and was supported by observational evidence. However, their study site was almost entirely enclosed by water and fences, greatly increasing the confidence in their estimate. Additionally, spotlighting is not a feasible method to index a cat population in jarrah forests, as are cats secretive and almost never observed (Wayne *et al.* 2001). Marks *et al.* (2009) used IMI methods for assessing fox abundance in Victoria with sandpads (more feasible for jarrah forests) along with spotlighting as abundance indices and poisoning with cyanide as manipulation. However, as has been noted previously (Allen *et al.* 1996, Edwards *et al.* 2000), after the removal of some individuals by poisoning, the activity of the remaining population increased and skewed the sandpad results.

Short and Turner (2005) also undertook a successful density estimation effort through intensive trapping, shooting, and poisoning in a 12 km^2 fenced reserve. They successfully removed all cats over a two-year period and obtained a former population density. Intensive removal efforts will ensure that the estimated population density is correct (or at least very accurate), as all or almost all individuals will be accounted for. However, it is very labor-intensive and difficult in the large-scale, especially in very large unfenced areas like the jarrah forest. Marlow *et al.* (2000), however, successfully removed almost all foxes from area of 200-km^2 to obtain a density estimate along mid-coastal Western Australia.

Spotlighting has often been used as an index of population abundance (Risbey *et al.* 2000, Short *et al.* 1997, Marlow *et al.* 2000, Short and Turner 2005). However, it will not yield an absolute measure of abundance without being paired and "calibrated" with another method that does provide an absolute measure of abundance (Bayliss *et al.* 1986, Risbey *et al.* 2000, Short and Turner 2005). Additionally, multiple studies have shown that spotlighting is a less effective population index for predators than sandpad surveys (Mahon *et al.* 1998, Edwards *et al.* 2000).

Track counts using sandpads have often been used as a method of assessing relative predator activities (Marks *et al.* 2009, Mahon *et al*. 1998, Edwards *et al.* 2000, Thompson *et al.* 2000, Allen *et al.* 1996). To date, there have been no attempts to derive estimates of population density from sandpad survey data. This study attempts to derive a population density estimate for foxes and cats in the jarrah forest of Southwest Western Australia from sandpad survey data. It also compares the effectiveness and efficiency of using sandpads and the effectiveness and efficiency of using motion-sensor cameras to assess the activity and movement of predators to contribute to that density estimate.

2. Methods

2.1. Study Area

The study took place in the jarrah forest ecoregion of Southwest Western Australia, mostly open *Eucalypt* woodland dominated by jarrah, marri (*Corymbia calophylla*), and wandoo (*E. wandoo*). The region has a warm Mediterranean climate, with an inland annual rainfall of 600-700 mm. The sandpad survey sites were spread over a an area of about 875 km^2 including land in the Tone Perup Nature Reserve, the "Greater Kingston" National Park (unofficial name), and Kingston state forest just east and northeast of Manjimup, WA. Together, these areas of forest managed by the Western Australian government's Department of Environment and Conservation (DEC) make up the Upper Warren region.

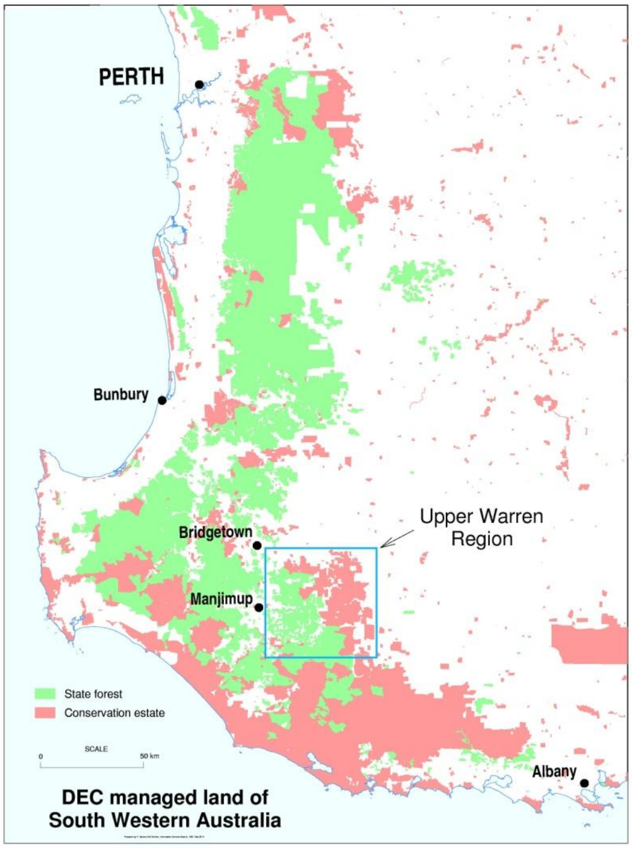

Figure 1. Conservation land and state forest in Southwest WA. Sandpads were all located within the Upper Warren.

There were six sandpad arrays, each named after the forest block where it was located: Keninup, Balban, Boyicup, Moopinup, Winnejup, and Warrup. All arrays had generally similar habitats and climates due to their proximity, but there were small differences in rainfall, vegetation, proximity to private pasture land, and area covered by the array that are not discussed in this report.

2.2. Sandpads

Sandpads were laid out, for the most part, in accordance with the suggestions of Allen and Engeman (1995). Each array contained 25 sandpads—a strip of sand one meter-wide dug across the width of the road. Pads were spaced 500 meters apart, and each array followed seldom-driven park roads. All tracks were checked and recorded in the morning and sand was smoothed with a rake and broom. The process was repeated every morning for six mornings from 27 March through 1 April, 2012. Tracks were divided into seven categories: cat, fox, chuditch (Western quoll), woylie, other macropod, possum, and other. Each set of tracks

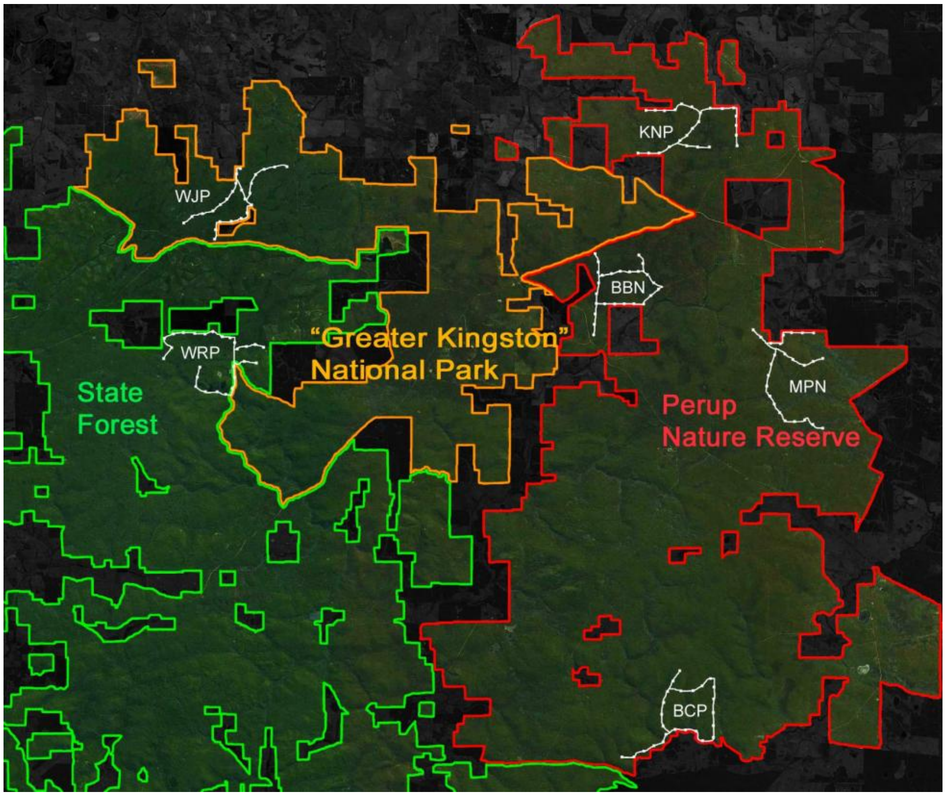

Figure 2. Sandpad arrays and their arrangement in the Upper Warren. WJP = Winnejup, KNP = Keninup, WRP = Warrup, BBN = Balban, MPN = Moopinup, BCP = Boyicup.

recorded was given a certainty rating from one to three, one being certain, two being probable, and three being possible. Tracks recorded under "other" were also identified and given a certainty rating. For cats and foxes, direction and activity on the pad was also recorded. On every pad, a clarity marker (a handprint) was placed in the morning over the road wheel rut after the pad had been smoothed over. If the marker was no longer visible the following morning, whether because of vehicle tracks, wind, rain, etc., that pad was removed from consideration for that day.

2.3. Analysis

Calculating an index for activity was based on Allen and Engeman (1995), called the Allen's Activity Index. Calculating an index for each study day requires dividing the total number of pads with recorded activity of a given species by the total number of available pads for that day. The overall activity index (AI) for a single session is the average of the indices from each day.

The convention (for foxes and cats) for attempting to determine how many individuals have been active in a sandpad array is to assume that every break in activity of more than one kilometer is a break between two individuals (Allen *et al* 1996). The possible flaw in this method is that enough activity will eventually result in a sole individual being identified, rather than many. Therefore, in order to determine if this is an effective way of assessing individual activity, AIs were compared to number of estimated individuals for each day at each site from the March 2012 survey and from previous surveys (2008-2011), with the assumption that a strong relationship implied a good estimate of number of individuals.

2.4. Cameras

For three of the nights of during the study, one Reconyx HC600 Hyperfire High Output Covert IR motion sensor camera was placed, facing along the sandpad at each of 25 total pads across five of the six sites. Batteries for the cameras were changed whenever necessary. Because no past data exists for cameras and because there were only 25 total cameras to cover 150 sandpads, data from cameras were not used to contribute to a density estimate, but rather just as a comparison between camera and sandpad in terms of effectiveness and efficiency in order to inform a recommendation regarding the more extensive use of cameras in the future.

3. Results

3.1. Sandpads

The average fox AI was 0.127 for the March 2012 session and 0.131 for all sessions combined (Feb ’08, Aug ’08, Mar ’09, Mar ’10, Mar ’11, Sep ’11, Mar ’12). Average cat AI was

0.046 for the March 2012 session and 0.047 for all sessions combined. For all sessions, average fox AI was 0.182 at Keninup, 0.162 at Balban, 0.100 at Boyicup, 0.103 at Moopinup, 0.136 at Winnejup, and 0.081 at Warrup. Average cat AI was 0.050 at Keninup, 0.034 at Balban, 0.043 at Boyicup, 0.085 at Moopinup, 0.036 at Winnejup, and 0.051 at Warrup.

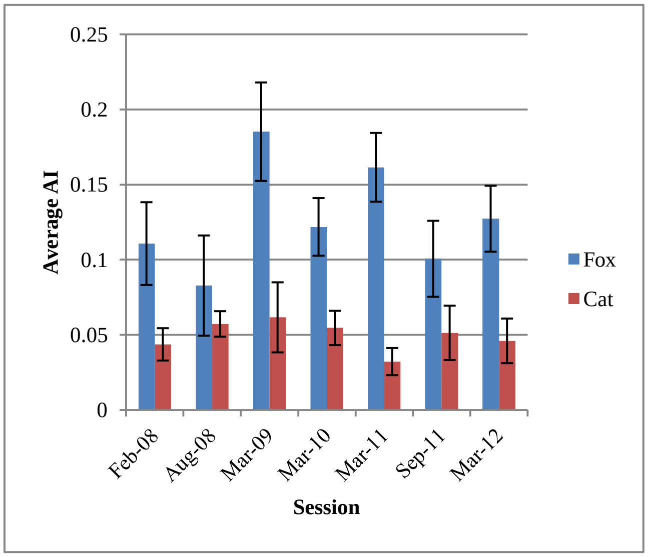

Figure 3.a. Average fox and cat AI by session

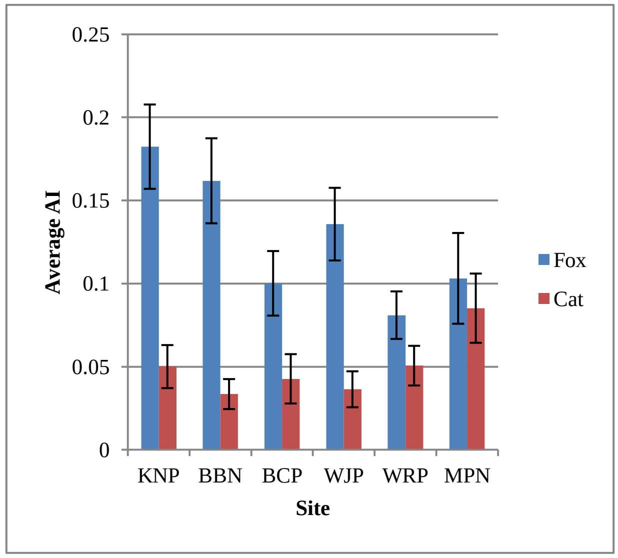

Figure 3.b. Average fox and cat AI by site

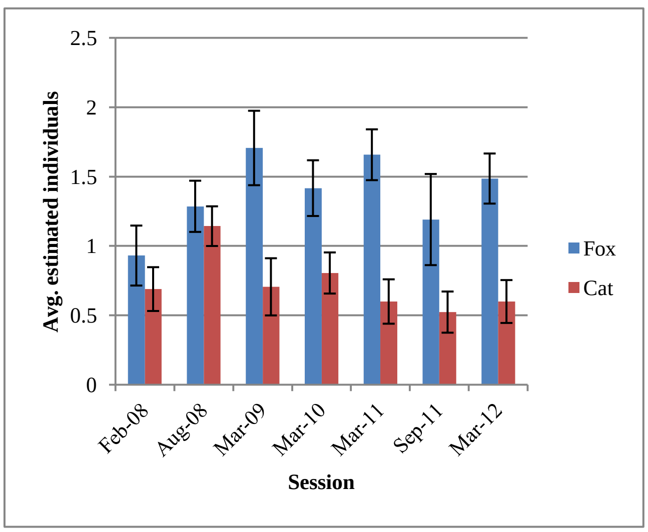

Figure 4.a. Average estimated fox and cat individuals by session

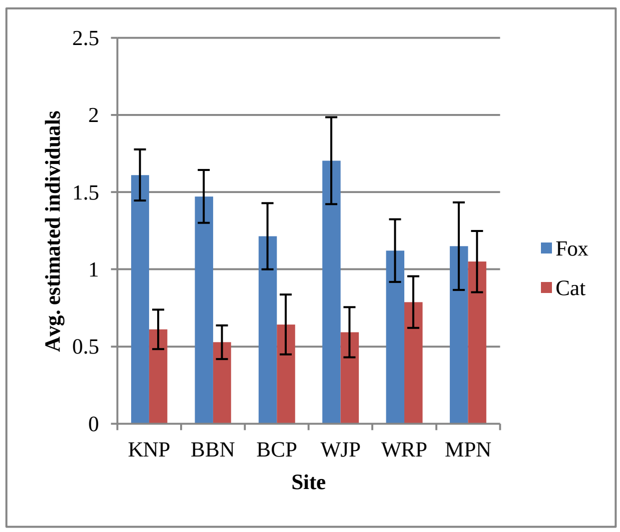

Figure 4.b. Average estimated fox and cat individuals by site

Fits of the linear regressions of AI to estimated individuals were variable between sites. For foxes, the comparison was worst at Keninup (R^2=0.387) and Balban (R^2=0.584) and best at Moopinup (R^2=0.868) and Winnejup (R^2=0.726). Cats, the comparison was worst at Keninup (R^2=0.612) and Moopinup (R^2=0.626) and best at Boyicup (R^2=0.878) and Winnejup (R^2=0.866). It was determined that sites appropriate to attempt to derive a density estimate were Winnejup and Moopinup for foxes and Balban, Boyicup, and Warrup for cats.

Dice's (1938) method was used to estimate density using average home range size. However, no home range studies for predators have been published for the jarrah forest, so a range was used based on previous studies in Australia (foxes: Meek and Saunders 2000, Coman *et al.* 1991, Phillips and Catling 1991; cats: Bengsen *et al.* 2012, Smucker *et al.* 2000, Edwards *et al.* 2001, Langham and Porter 1991) of 1.2-4.0 km^2 for foxes and 1.7-5.0 km^2 for cats. From this range, a fox density of 0.081-0.119 km^{-2} for Winnejup and 0.097-0.140 km^{-2} for Moopinup and a cat density of 0.073-0.107 km^{-2} for Balban, 0.136-0.204 km^{-2} for Boyicup, and 0.019-0.028 km^{-2} for Warrup was calculated. All regressions were calculated with Microsoft Excel 2007.

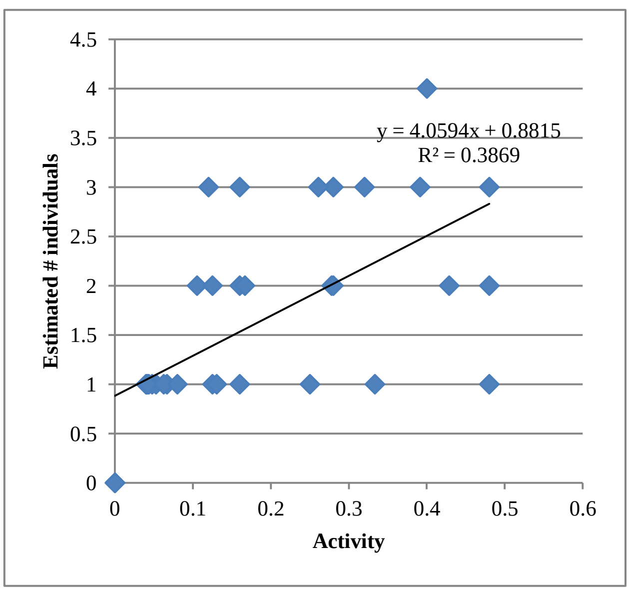

Figure 5.a. Estimated fox individuals versus activity at Keninup across all sessions

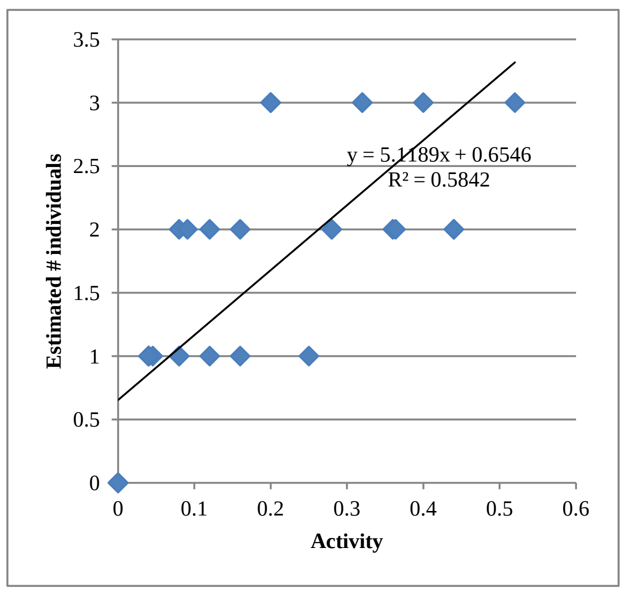

Figure 5.b. Estimated fox individuals versus activity at Balban across all sessions

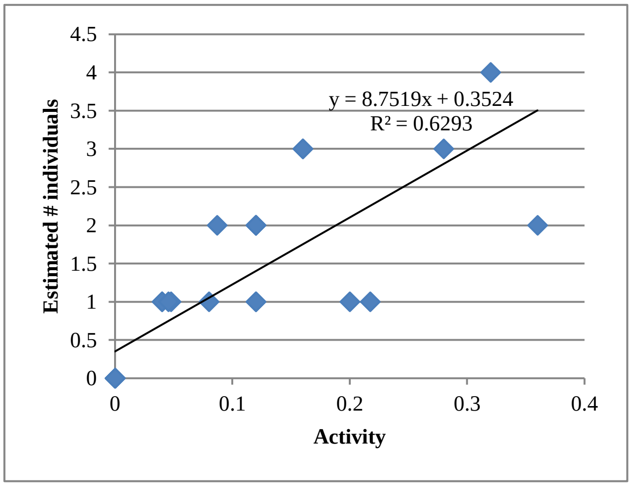

Figure 5.c. Estimated fox individuals versus activity at Boyicup across all sessions

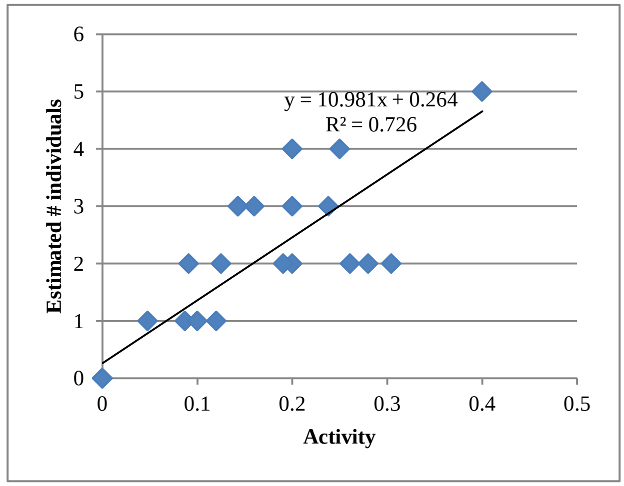

Figure 5.d. Estimated fox individuals versus activity at Winnejup across all sessions

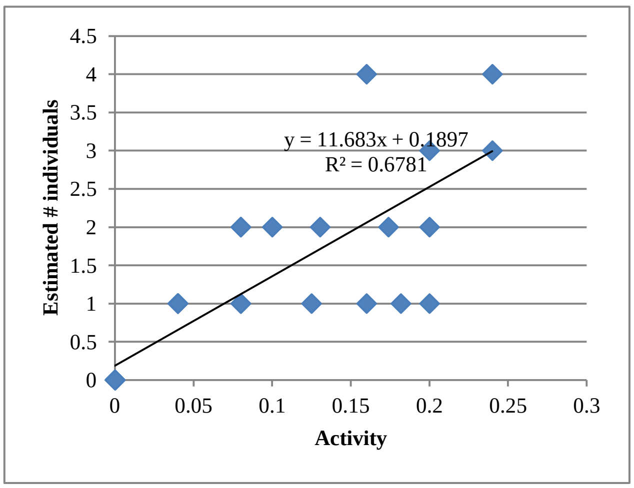

Figure 5.e. Estimated fox individuals versus activity at Warrup across all sessions

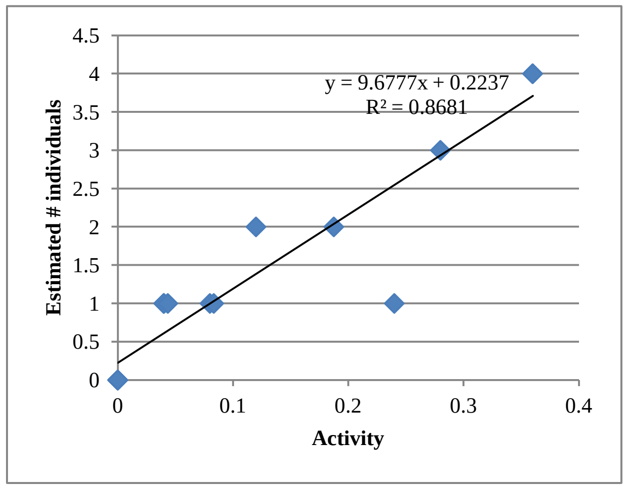

Figure 5.f. Estimated fox individuals versus activity at Moopinup across all sessions

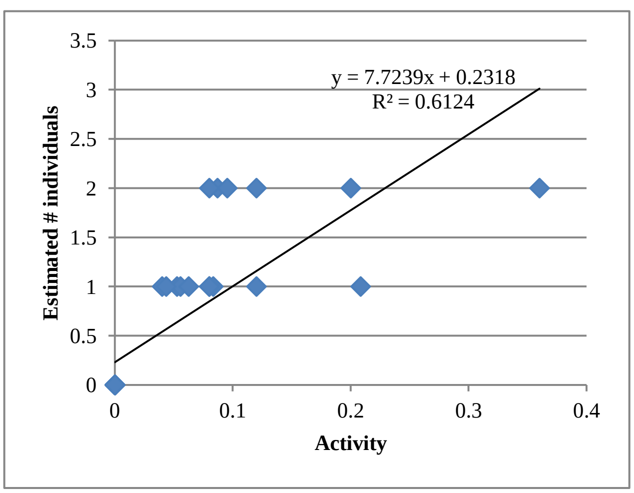

Figure 6.a. Estimated cat individuals versus activity at Keninup across all sessions

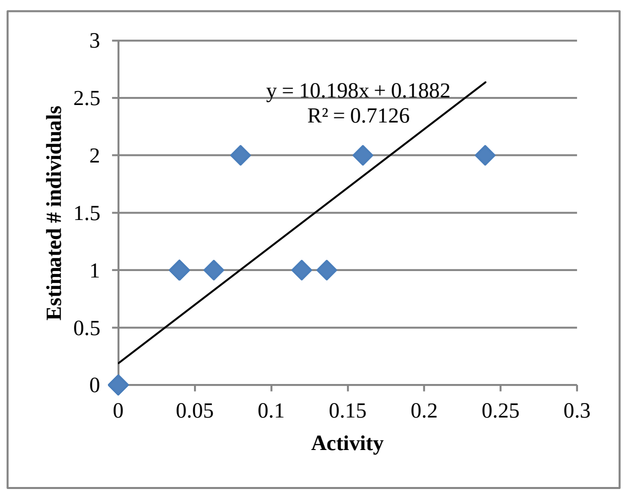

Figure 6.b. Estimated cat individuals versus activity at Balban across all sessions

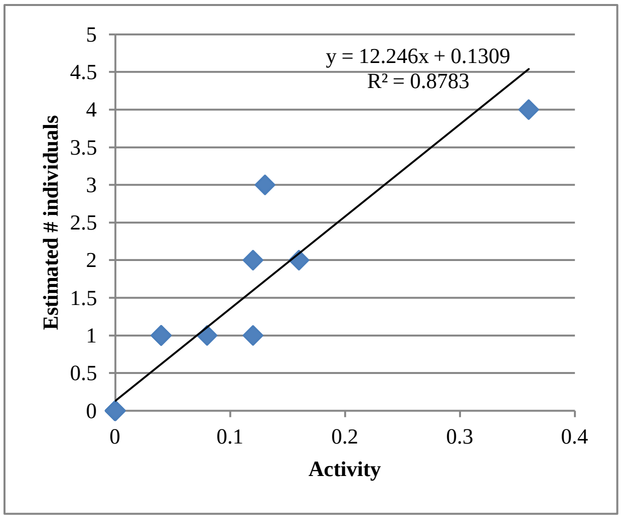

Figure 6.c. Estimated cat individuals versus activity at Boyicup across all sessions

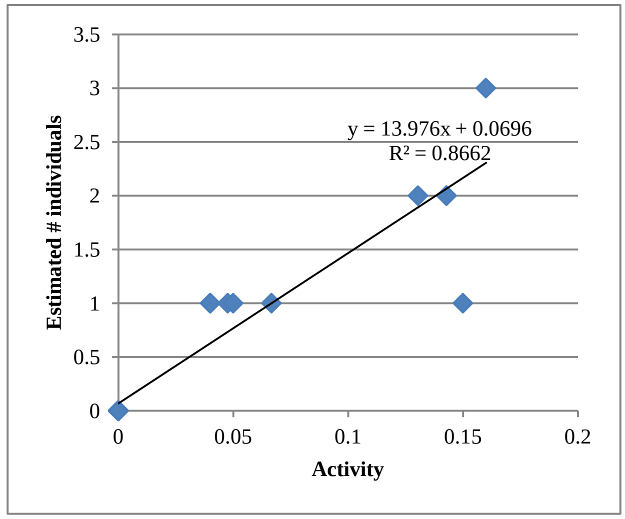

Figure 6.d. Estimated cat individuals versus activity at Winnejup across all sessions

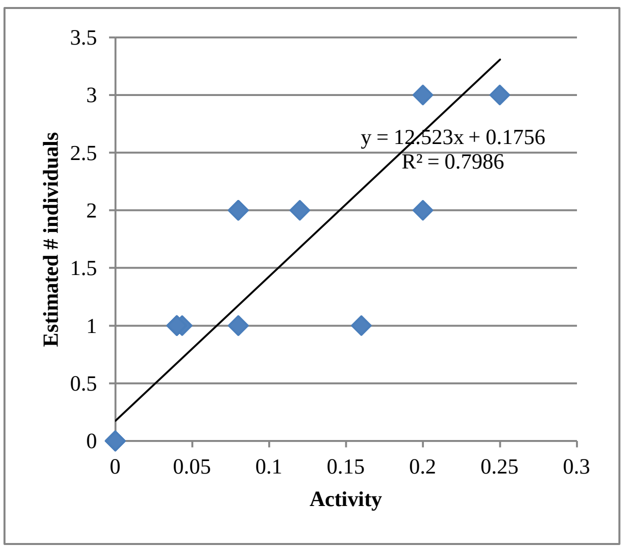

Figure 6.e. Estimated cat individuals versus activity at Warrup across all sessions

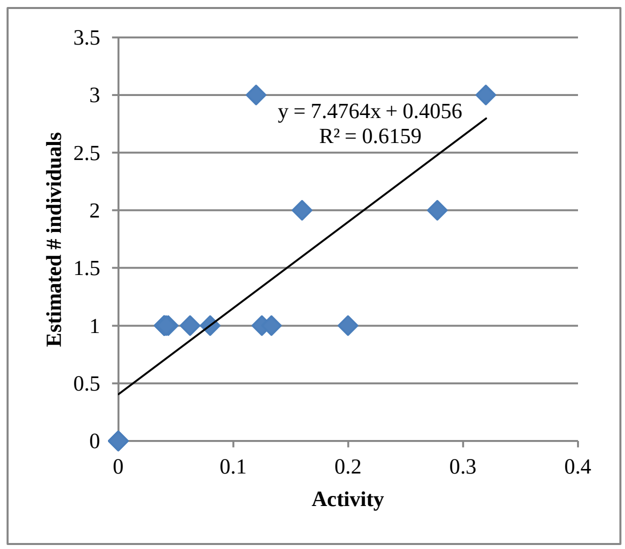

Figure 6.f. Estimated cat individuals versus activity at Moopinup across all sessions

3.2. Cameras

Overall, cameras detected more individual animals than sandpads. Sandpads (that were paired with a camera) detected 10 foxes (76.9% of total), none of which were not also detected by cameras. Cameras detected 13 foxes (100% of total), 3 of which were not also detected by sandpads. Sandpads detected 4 cats (100% of total), one of which was not also detected by a camera. Cameras detected 3 cats (75% of total), none of which were not also detected by sandpads. However, it is likely (though not certain) that the one night in which a cat was detected on the sandpad but not the camera, there had been an error in camera setup.

Figure 7. Example of a fox that was detected by a camera, but not by the sandpad. In this case, the fox was not detected because it did not cross over the pad.

There were also two instances in which two foxes were detected by the camera. In one of these instances, no foxes were detected by the sandpad, and in the other, one fox was detected. However, without any method to identify separate individuals, both instances were recorded as two crossings of one fox.

4. Discussion

4.1. Sandpads

The derived density estimates for both foxes and cats were significantly lower than previous estimates for predator density necessary to account for the recent woylie decline (Wayne *et al.* 2011). This could imply that there are other factors, such as disease, negatively impacting woylie survival. This could also imply that the method used to derive these low estimates requires too great a leap from recorded data to estimate.

Given the discussed limitations of sandpads, it is very likely that numbers of individual have been underestimated due to large amounts of activity leading to many consecutive sandpad detections and fewer individuals estimated. It is also possible that the method for deriving density from number of individuals overestimates catchment area due to the non-grid nature of the sandpad arrays. It is also likely that a six-day survey is not enough time to produce accurate estimates of predator activity. Predator activity varied greatly from day to day.

4.2. Cameras

4.2.1. Effectiveness

The addition of cameras proved an effective way of detecting predators. Once technical issues are resolved, cameras have a better detection ability than sandpads, as they are not limited by wind and rain, vehicles, or space. Identifications even of clear tracks are certain, rather than relying on inferences. Cameras are also effective at differing between individual cats by markings, and, if cameras were placed at every point along an array, individual foxes by direction and timing. They have the ability to detect if two animals are together or interacting. In this study, a fox was captured on camera holding a predated possum in its mouth. Other animal species were captured together on camera as well (possums, woylie and Western grey kangaroo, emus).

The greatest limitations in deriving density estimates from sandpad data alone stem from the fact that sandpads only provide activity levels, rather than individuals. With a grid or array of cameras, individuals, activity, and behavior could all be positively identified.

4.2.2. Efficiency

Cameras for this study required a one-time cost of about $17,000. In the future, that cost would apply to enough cameras to cover each sandpad at a single site. Running costs (not including salaries) for seven days at a single site (including setup) would be about $1,000, assuming cameras were checked every day by one vehicle and about $300, assuming the cameras were only accessed when being set up and taken down, as well as about $1,000 for batteries per session.

Sandpads require a one-time construction cost of about $5,000 and running costs (not including salaries) for a session of about $1,000 per site for vehicles and about $2,500 for sand.

Cameras require a much larger initial cost, and, if paired with sandpads, do not reduce running costs. However, cameras not paired with sandpads require significantly less running costs and will be less expensive and time-consuming in a long-term study.

5. Conclusions

This study adds to the body of work involved in ultimately determining the impact of feral animals on native Australian ecosystems. The findings above imply that density estimates based on sandpad data alone may not be sound enough to inform management decisions. However, the addition of remote sensor cameras may be a more effective and more efficient means of deriving these estimates.

The efficiency and cost comparison of cameras to other, previously mentioned methods of estimating density will be relatively similar to the comparison to sandpads. Sandpads are the most effective, practical method in the jarrah forest for calculating a relative activity index, but they should be used in an IMI study in order to determine density. Trapping, shooting, and poisoning is more difficult in the jarrah forest (especially for cats) and is very labor-intensive, but it produces a good absolute abundance estimate.DNA CMR is expensive and labor-intensive, but is one of only a few methods that can be effective for cats. Further studies should test the utilization of cameras in producing an independent density estimate, perhaps paired with another method of density-estimation. Based on the results of this study, cameras should be effective to this end.

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