Population density of Malay Civets (*Viverra tangalunga*) within Lot's 5, 6 & 7 of the Lower Kinabatangan Wildlife Sanctuary (LKWS) in Sabah, Malaysia

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Preface

As I sit here on home soil, giddy on a tidal wave of nostalgic relief to be surrounded by the friends, family, and familiar sights of my beloved hometown of Bristol; it is with an absolute sense of wonder that I have the privilege to reminisce about being in a place so alien, so exciting, and so enriching for an entire ear of my university career, and more importantly, life. It's been an experience I would not trade the world for, and I would like to foremost thank every person, institution and animal that has been a part of such a truly life-changing experience.

My professional training year has provided ample enrichment in a bunch of unexpected ways! The experience of living and working in the same place, with the same people, in isolation, has fostered my understanding and ability for professional and personal communication amongst my colleagues, alongside my capacity to recognise and manage my own emotional state in order to remain productive and social. What I consider to be one of the most valuable character traits I have developed this year is the mental resilience to push through times that are tough. Certainly, there were times when the physical toll of field work in a tropical climate full of insects and plants that can irritate you if you're not careful, coupled with the isolation, made me feel sad or uncomfortable; but the people I shared these experiences with and the compassion and understanding they showed for me and each other has given me such an appreciation for every staff and research members social and professional skills and integrity. I have built such solid friendships with my fellow PTY students especially, but also all of the other researchers, volunteers, and research assistants, which at the end of the year has left me in the fantastic position of having friends all over the world, from all walks of life, yet all sharing and involved in the same interests.

Some additional skills I have developed this year that I am proud of is my ability to speak the Malaysian language, as I made a strong effort to learn and practise with my Malaysian colleagues and as a result have built stronger friendships with them and acquired greater appreciation of Malaysian culture. Furthermore learning to speak Malaysian has increased my confidence and aspiration to learn other languages. I have also improved my photography skills. As a result of receiving the Karen Folk scholarship I was able to purchase camera equipment to bring to Borneo, and throughout the year have enjoyed practising wildlife photography and building up a collection of images to share my incredible jungle experience with friends and family. Lastly, throughout my PTY I took up drawing as a hobby, and also spent much of my free time exercising. By virtue of being creative artistically, and also thinking outside the box to find new, fun ways of exercising with little equipment available, I feel as if I have improved my ability to think creatively and improvise.

Upon completing my PTY in Borneo, I feel incredibly satisfied with the knowledge, friendships, skills, and maturity this year has given me. I am extremely grateful to all the support from my friends, family, colleagues and Benoit Goossens who have been instrumental in giving me this fantastic experience, and secured my intentions of pursuing a career in Wildlife and conservation research.

Abstract

The tropical rainforests of Borneo in Southeast Asia are experiencing one of the highest deforestation rates in the world, the majority of which is driven by logging interests and agricultural palm oil plantations. Most areas of forest not converted outright have still suffered degradation by selective logging – the principle method of timber extraction in the tropics – with the effect of reducing sapling abundance, canopy height and seed production, alongside changing microclimate conditions in remnant patches. In such a rapidly changing environment it is crucial to monitor the population sizes of inhabitant wildlife as a means of measuring the overall ecosystem health. Camera traps are growing to be an ever more powerful and popular tool for monitoring population densities, occurrence, distribution and behaviours, because unlike traditional methods for surveying populations, such as single and multiple catch traps that actually hold the animal for duration of time, camera traps act as "proximity detectors" whereby a passing animal's presence and identity is recorded regardless of previous 'captures'. Using camera traps, this study determines the population density of Malay civet *Viverra tangalunga*, a small omnivorous member of the *Viverridae* family and an important generalist species known to be sensitive to forest degradation, within forest fragments of close proximity to palm oil plantation located throughout lots 5, 6 & 7 of the Lower Kinabatangan Wildlife Sanctuary. 5 camera trap grids were deployed over 4 months as a capture-recapture style survey whereby individual animals were recognised via their coat pattern by eye. Five distinct camera trap grids were established for this study, however only one grid returned results that could be effectively used to identify individuals of the species. Ultimately, this study produced a Spatially Explicit Capture Recapture (SECR) model to calculate Capture probability modelled as a function of distance from the centroid (single location associated with animal) to traps. Resulting in a density estimate of 3.2 individuals per sq km.

Introduction

The tropical rainforests of Borneo in Southeast Asia are experiencing one of the highest deforestation rates in the world with approximately 1.7% of its forest converted annually (Koh, 2007), the majority of which is driven by logging interests and agricultural palm oil plantations (Laurance 2007). Most areas of forest not converted outright have still suffered degradation by selective logging – the principle method of timber extraction in the tropics – with the effect of reducing sapling abundance, canopy height and seed production, alongside changing microclimate conditions in remnant patches (Brodie and Giordano, 2011). Furthermore due to repeat cycles of selective logging (86% of the logged forest in Borneo has been logged at least twice), the recovery rates of these forests have been significantly impeded (Bryan et al., 2013). What little of Borneo that has been afforded protected status (roughly 9% under IUCN categories I-IV as defined in 1994) exists in patches that are becoming increasingly more isolated (Curran 2004). Additionally, wildlife within these protected areas continue to face internal threats such as hunting for food, medicine, and the exotic pet trade, as well as stressors from illegal logging and mining (Brodie and Giordano, 2011).

Culminating the effects of rapid forest degradation, exploitation and fragmentation throughout Borneo along with internal threats of poaching faced by its wildlife; amounts in an environmental crisis whereby one of the planets most biodiverse ecosystems may be lost, along with the many of the unique flora and fauna it supports. It is therefore crucial to evaluate the population status of wildlife species within such threatened environments. Quantifying the abundance and diversity of wildlife species within a given habitat is paramount in evaluating the status of its population and further discerning the weight its ecological role. An important biological practise worldwide, measuring population size as a means of wildlife monitoring whereby unstable population trends (such as population increases or decreases) are recognised, subsequently allow for preventative or reverse action to be taken preceding the employment of management plans with which the population can ultimately be stabilised.

Camera traps are growing to be an ever more powerful and popular tool for monitoring population density, occurrence, distribution and behaviour for a number of reasons. Unlike traditional methods for surveying populations, such as single and multiple catch traps that actually hold the animal for duration of time, camera traps act as “proximity detectors” whereby a passing animal’s presence and identity is recorded regardless of previous ‘captures’ (Borchers, 2010). This makes camera traps one of the least invasive methods of recording individual animals or species occurrence, and compared to the effort required of a researcher conducting field surveys, camera traps pose minimal disturbance to the natural behaviours of target wildlife. Camera traps also have the capacity to store large amounts of data, and given sufficient power supply, can remain continuously active for over a month. Thus, despite the high initial costs of camera trap deployment both as a resource and work-hours spent transporting, operating and setting up the traps, the resultant low maintenance nature of cameras traps ultimately outweighs this initial expense, making camera traps an economically preferable method for collecting larger-scale population data sets.

The Malay civet (*Viverra tangalunga*) is a small omnivorous member of the *Viverridae* family native to Malaysia. Previous research proposed *V. tangalunga* to be sensitive to anthropogenic disturbance, with a recorded 20% drop in local population 1 year following selective logging and no subsequent recovery over the next 5 years (Jennings et al., 2010). Furthermore, a comparative study carried out between primary and secondary forests of Peninsula Malaysia found population densities of *V. tangalunga* to be far lower in disturbed and selectively logged forest (6.4 individuals per sq km) than in primary forest (31.5 individuals per sq km) (Heydon and Bulloh, 1996). Together with its predatory position in the food chain, these factors highlight *V. tangalunga* as a species not only in need of surveillance amongst secondary forest habitats but also as a valuable contributor to ecosystem functions, thus capable of indicating the overall health of the ecosystem it exists within.

The purpose of this study was to determine the local population densities of *Viverra tangalunga* throughout Lots 5 & 6 of the Lower Kinabatangan Wildlife Sanctuary via a Capture-Recapture style survey consisting of five distinct camera trap grids, which would provide individual encounter histories and spatial data suitable for use in a Spatially Explicit Capture Recapture (SECR) model capable of determining population density.

Materials and Methods

A total of five distinct camera trap grids named A, B, C, D, and E, each irregular in shape, were deployed within Lots 5, 6 and 7 of the Lower Kinabatangan Wildlife Sanctuary (LKWS) during the year 2017 (see Figure 1)

Grids A, B, and C, were set up during the last week of February and taken down 8 weeks later in April. Grids D and E were set up during late April and taken down 8 weeks later in June (see Table 1).

Grid	No. of Stations	Date set up	Date taken down	Active trap nights	Potential trap nights	LKWS forest lot
A	6	27/02/17	24/04/17	538	658	6
B	7	28/02/17	25/04/17	667	762	7
C	9	23/02/17	20/04/17	841	1010	6
D	10	22/04/17	20/06/17	752	1790	5
E	13	24/04/17	20/06/17	881	1824	6

Table.1:
For each camera trap grid: Details quantity of trap stations (2 cameras per station), date the first and last trap station was set up/taken down respectively, total number of active (and potential trap nights accumulated across all cameras throughout survey period, and which LKWS forest plot the trapping grid resides in

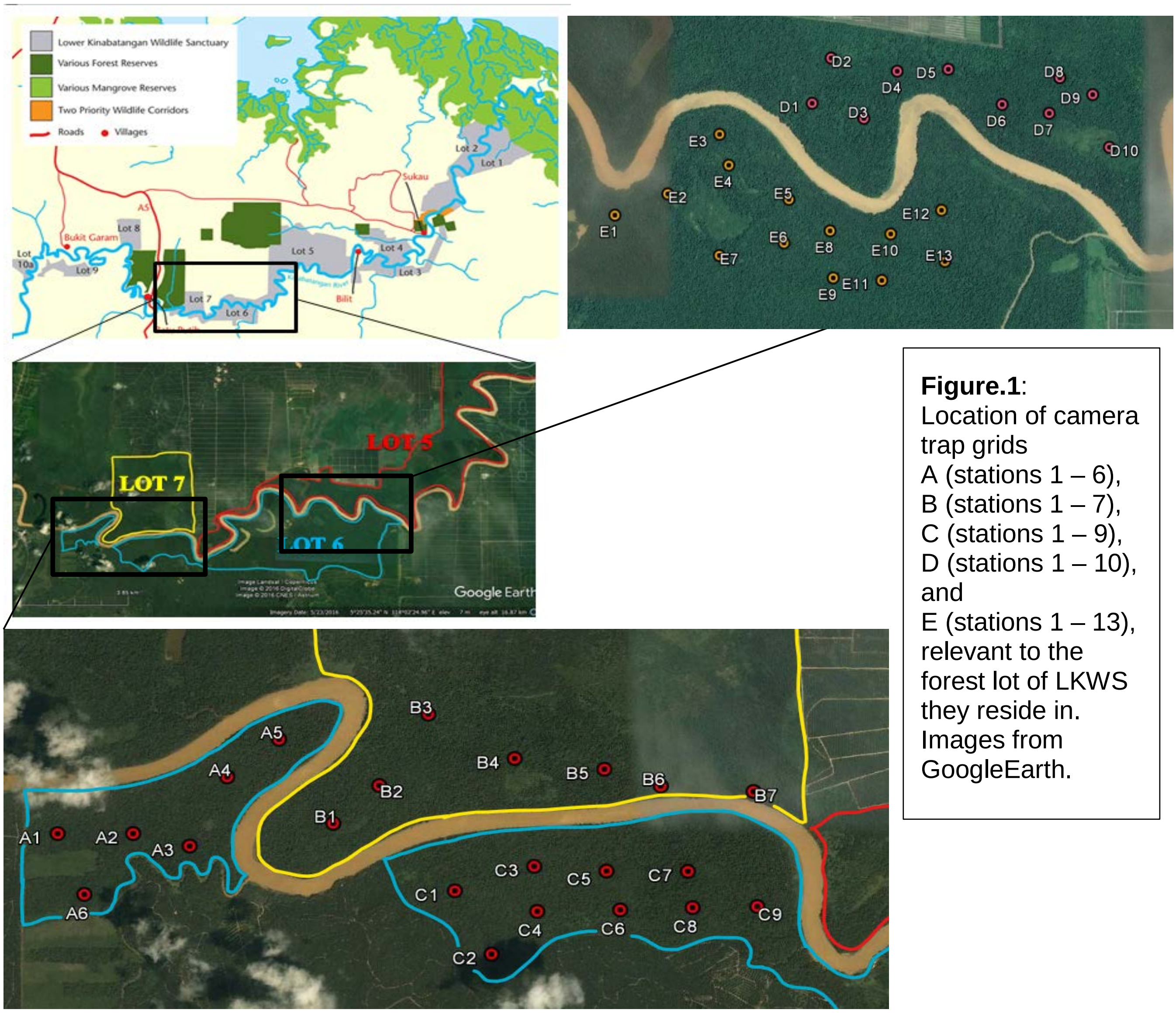

Figure.1:
Location of camera trap grids
A (stations 1 – 6),
B (stations 1 – 7),
C (stations 1 – 9),
D (stations 1 – 10), and
E (stations 1 – 13), relevant to the forest lot of LKWS they reside in. Images from GoogleEarth.

The prospective location of camera trap stations were decided and mapped out using Google earth. Within their respective grids, each camera trap station were set as close to a maximum of 500m away from other trap stations as well as any hard boundaries such as the Kinabatangan river, to ensure no gaps large enough to accommodate an individual *V. tangalunga's* home range, taken to be 1.1km^2 for an active adult or 500m^2 for a pregnant female (Colón, 2002), existed between stations. Camera trap stations consisted of two individual camera traps set to face each other no more than 7m apart across a clearing or animal trail. The proposed location for each camera trap station was downloaded onto a GPS Garmin device in order to locate each station site in the field. Once in the forest, camera traps were set within a 50m radius of the initial GPS marker according to the suitability of trees on which to attach the cameras as well as the presence of trails, fruits, and water. The exception being stations B4, B5, B6, & B7 which were all positioned >50m south of the proposed location due to unforeseen flooding throughout the forest plot.

A total of 90 PC800 and HC500 Reconyx Hyperfire professional Infrared (IR) camera traps were used throughout the study period, each of which utilised 12 rechargeable batteries and an 8GB SD card whilst active. All camera traps were set to take 3 photos at 1 second intervals upon detection of a 'warm' movement. Each 3 photo sequence per trigger was considered a single photo event, whilst all photos in a sequence without gaps of more than 120 minutes was considered a single photo occasion. Camera taps were checked once per fortnight in order to replace the SD card and enough batteries for the camera to display a battery percentage of >50% NIMH. Throughout visiting camera traps in the field and looking through the images each had taken, careful attention was paid to each camera's performance regarding sensitivity to movement, functionality of IR flash and ability to take night photos, typical battery life and time stamp to ensure the cameras internal clock was set correctly.

Setting up each camera trap was standardised according to the following routine (see figure 2):

- Camera traps protected inside a metal case secured to the base of a tree by screws. A bungee cord will also be used to secure the casing lid to the tree in order to prevent tampering by macaques.

- Camera traps positioned 40cm high off the ground, roughly at equal height to the flank of *V. tangalunga*

- Camera traps placed, when possible, along animal trails so as to maximise capture potential

- Both camera traps at a site face each other, but not directly so as to avoid simultaneous IR flash interference

- Vegetation cleared so as not to obstruct the view between opposing camera trap pairs

- Silica gel packets placed at each of the four corners inside the camera trap to avoid moisture build-up

- Distance between the two camera traps at a single station no greater than 7m and no less than 3m

- Functionality of camera traps was tested by performing a “walktest”, whereby each camera trap would be programmed to flash a red light upon detection of a warm movement that would trigger a photographic sequence. A researcher would then move about in front of the camera to check that the camera was detecting movement in the desired location.

Furthermore the following variables were recorded at each camera trap station throughout the study period:

- Distance to any nearby anthropogenic disturbances or features (i.e. palm oil plantations)

- Presence of any nearby water source

- Presence of fruiting trees

- Presence of any prominent environmental features such as boulders or fallen trees

- A continuous record of the number of operational camera trap days per site, whereby one camera trap day = number of active camera traps in total X total number of calendar days

- Distance between the 2 camera stations at each trap site

- All camera trap failures and malfunctions

- All photos of unidentifiable individuals

Figure.2: Weatherproof metal case for camera trap drilled into a tree, where midpoint of casing is 40cm high.

Camera trap grids were effectively active for no more than 2 months to prevent demographic or geographic variance within the population, allowing for more robust statistical results. The exception being several cameras, particularly in grid D, that were irretrievable due to cut off by flooding. Upon eventual collection of the photos from any camera that remained in the field beyond the 2 month survey period, no images of *V. tangalunga* that could be used to identify the individual were found; therefore no results outside of the survey time frame were entered into the data. Values for active and potential trap nights were calculated by camera and do include total amount of time each camera was active or deployed, regardless of whether the time range exceeds the trap survey period.

Individual *V.tangalunga* observed via the camera traps were identified from the images using their unique spot/stripe markings by eye (see figure 3). In order for a complete identification of an individual civet to be made required having clear and comparable images from both sides of the animal. This can be achieved by having a pair of cameras facing each other at each station, as is the case in this study, in order to detect and record images both sides of an animal that moves between the camera traps. The images produced by each camera can then be matched by their time stamp to certify that they represent both sides of the same animal from the same encounter. Alternatively, a positive ID for both sides of an animal could occur from a single camera so long as the animal turns around in front of the camera, so that it displays both flanks within one image sequence. Once any images displaying either flank of an animal are identified to belong to the same individual, complete identifications can subsequently be made from any image clearly showing at least just one side of the animal. Once all *V. tangalunga* individuals had been identified, image files were organised through use of the package “camtrapR” which is run through the statistical program “R”. Images were arranged via station/camera they belong to as well as had their name adjusted to include the animals’ individual ID alongside the time picture was taken and by which camera. Furthermore, individual record, encounter history and camera operation tables were also produced.

Figure.3:
Images from 2 distinct trapping occasions at different stations (left = C3, right = C5) of the same civet, identified by the unique coat pattern on its neck, stripe pattern on the tail, and spot distribution on the rump.

Using Mark Recapture methods enabled through individual identification, population abundance and subsequently density were estimated under the assumed parameters for a fixed population demographic within a defined geographical area. Using the “secr” package in “R” software, a Spatially Explicit Capture Recapture model was applied to the accrued image data which used spatial information from captures to model animal movement within and beyond the sampling grid and incorporated this data into density estimates. Ultimately, this study produced a Spatially Explicit Capture Recapture (SECR) model to calculate Capture probability modelled as a function of distance from the centroid (single location associated with animal) to traps. Because SECR models incorporate the location of traps relative to animals, they allow the question “what area do traps effectively cover?" to be answered in a statistically rigorous way from the capture–recapture data themselves. Non-spatial methods rely on methods which are at least partly ad hoc to convert abundance estimates to density estimates.

Researcher presence throughout a camera trap survey is valuable for the increased probability of witnessing additional data-points. For example, during a camera trap survey of small carnivores in the LKWS carried out from 2011-2015, five additional small carnivore species would have otherwise gone undocumented were they not spotted and identified by a researcher in the field (Evans et al 2016). However for the explicit purpose of determining the spatial densities of *V. tangalunga* as with this study, it would be statistically unsound to include any in-the-field observations of *V. tangalunga* with the camera trap data.

Results

Out of the five grids A, B, C, D and E, grid C produced the most appropriate data set for SECR analysis. Grids A, B, D and E had little success at producing reliably identifiable images of *V. tangalunga* due to high camera malfunction rates and extensive flooding and/or other natural barriers disrupting camera function, ability of researchers to check cameras, and ability of *V. tangalunga* to encounter camera traps. Therefore it is with the data from grid C that a density estimate was produced.

Grid C produced images for 32 distinct encounter occasions with *V. tangalunga* individuals, whereby each occasion is defined as happening at least 120 minutes after the previous recorded encounter. A total of seven different *V. tangalunga* individuals were successfully identified throughout the grid. The following is a survey report of the grid:

Station	setup_date	first_image_date	last_image_date	retrieval_date	n_nights_total	n_nights_active	n_cameras
C1	23/02/2017	<NA>	<NA>	20/04/2017	112	97	2
C2	23/02/2017	01/03/2017	01/03/2017	20/04/2017	112	109	2
C3	22/02/2017	24/03/2017	19/04/2017	20/04/2017	114	114	2
C4	23/02/2017	<NA>	<NA>	20/04/2017	112	112	2
C5	22/02/2017	22/02/2017	26/03/2017	19/04/2017	112	98	2
C6	23/02/2017	01/03/2017	17/04/2017	19/04/2017	110	87	2
C7	22/02/2017	<NA>	<NA>	19/04/2017	112	92	2
C8	23/02/2017	<NA>	<NA>	19/04/2017	110	67	2
C9	23/02/2017	<NA>	<NA>	19/04/2017	110	66	2

Total number of stations	9
Number of operational stations	9
Total number of cameras	18
n nights with cameras set up (operational or not)	1004
n nights with cameras set up and active (trap nights)	842
total trapping period	2017-02-22 - 2017-04-20

Station	Number of encounter events
C2	1
C3	16
C5	7
C6	8

Spatial data of each encounter occasion were mapped onto two plots (see Figures 4 & 5).

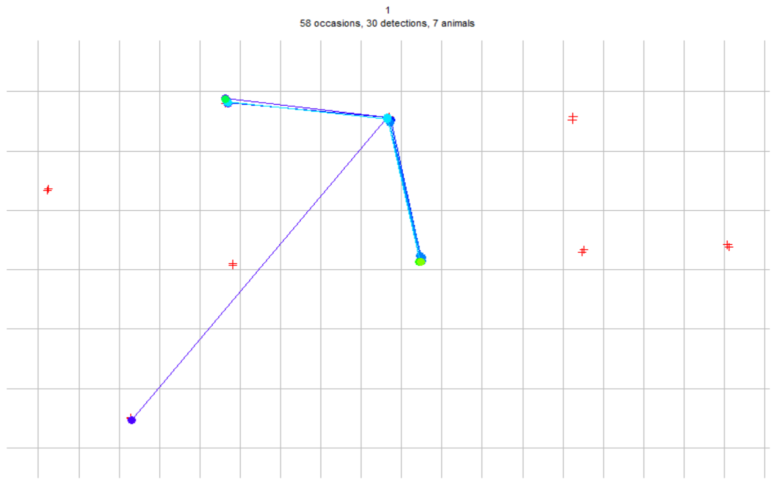

Figure 4:

V. tangalunga spatial capture data plotted in secr. Red crosses indicate trap stations. Dots represent individual civet encounter occasions and the lines connect encounters of the same individual

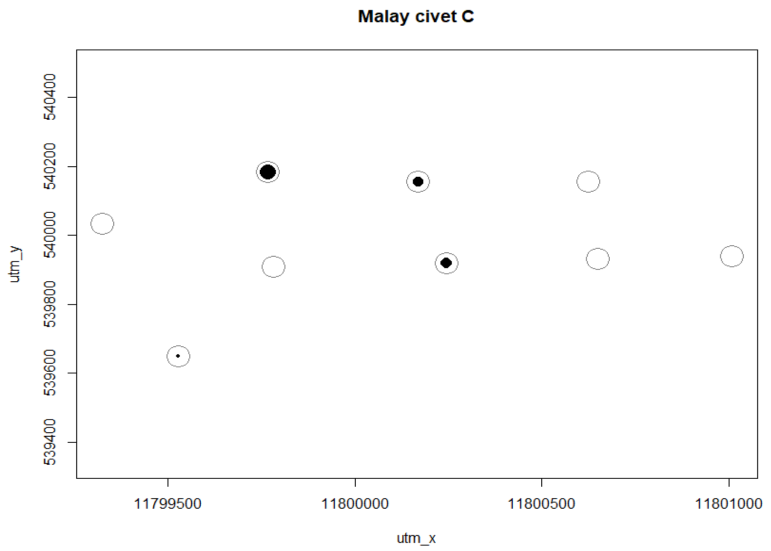

Figure 5:

V. tangalunga spatial capture data plotted in secr. Circles represent trap stations, black spots represent relative amount of individual encounters at each station. Larger black spots = more individual

Movement data recorded by calculating distance between successive encounter sites per individual was gathered as a useful indicator of how far each animal tends to range within the camera trap grid (see Figure 6)

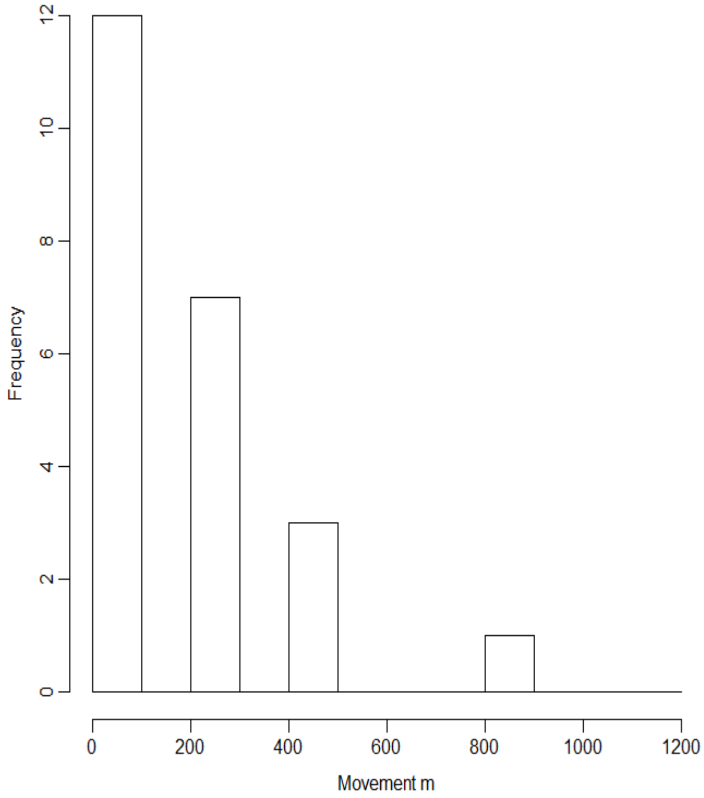

Figure 6:

Plot of distance between encounter sites for *V. tangalunga* individuals plotted in secr

Movement of *V. tangalunga* individuals determined through successive trap sites.
12 civets recorded to move <100m,
7 civets moved 200 – 300m,
3 civets moved 400 – 500m, and
1 civet 800 – 900m

Combining the data from *V. tangalunga* movement patterns (and subsequent estimated activity centres) with encounter rates enables a detection probability to be plotted (see Figure 7)

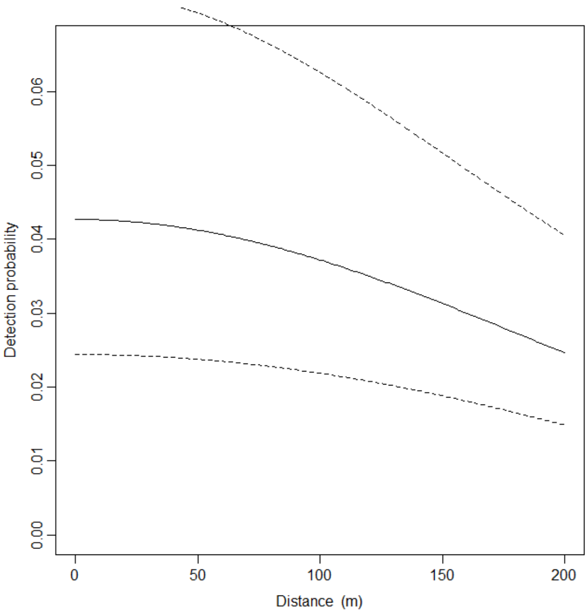

Figure 7:

Detection probability of *V.* tangalunga at any camera trap site relative to distance away the individuals activity centre is from trap site plotted in secr. Dotted lines = 95% confidence limits.

Several density estimates were calculated using three types of detection function: the ‘half-normal’ (HN), the ‘negative-exponential’ (EX) and the ‘hazard rate’ (HR). Each function produced a slightly different estimate of density D:

HN
D = 0.03125 individuals per hectare, = 3.125 individuals per square km
SE = 0.0133

EX
D = 0.03192 individuals per hectare, = 3.192 individuals per square km
SE = 0.0142

HR
D = 0.02662 individuals per hectare, = 2.662 individuals per square km
SE = 0.0129

While the Density estimates for HN and EX are very similar, a formal model comparison (AIC) shows EX to be the most suitable model.

HN
AIC = 329.341

EX
AIC = 335.030

HR
AIC = 342.451

Therefor the used result for predicted *V. tangalunga* population density within secondary forest patches throughout Lot 6 of the LKWS is 3.192 individuals per square kilometre.

Discussion

A population density of 3.2 per sq km for *V. tangalunga* is much less than previous estimates within secondary forest, yet it does still go to show that the species is present and somewhat common throughout historically disturbed, and currently very restricted, regions of the LKWS. Furthermore assuming a *V. tangalunga’s* home range can vary between 500m – 1100m dependant on sex and gravidity, the result of this study suggests several individuals can coexist with overlapping regions and as such are probably not strictly territorial animals.

There are several reasons why this study may have underestimated the density of civet populations.

The results from this study are entirely derived from the data accumulated within camera trap grid C, which generates an unreliably small sample size due to covering a very limited area, and only bearing results from 4 camera trap stations. Numerous camera traps throughout the trapping survey malfunctioned, or failed to take pictures of *V. tangalunga* clear enough for identifications to be made. More often than not, *V. tangalunga* walking between both camera traps at a particular station would only be effectively photographed by one of the camera pair. As such, very few 'double capture' events were recorded in which both sides of the same individual were photographed at a single occasion allowing for complete identification of the individual. That being the case, most complete civet identifications was determined from image sequences of an individual civet showing both sides of its body. As this did not happen often, there were multiple encounter occasions with *V. tangalunga* in which the individual could not be identified and the data therefor omitted from the final results analyses. What could have been done to improve the effective capture rate of *V. tangalunga* at each station would have been to use bait. By attracting each individual into the middle of the paired traps at a station, and enticing them to stay for a longer time, would have greatly increased the abundance and quality of images acquired. As this study relied upon identifying individuals of the target species, use of bait would not have produced a resultant bias through overestimating abundancy.

Another issue with the study was the prevalence of unknown habitat factors likely affecting the data. Throughout managing all of the grid sites it became apparent that many barriers to movement, such as tributaries and regions of flooding existed inside the camera trapping grids. Without being able to account for the effect of geographical boundaries affecting the spatial distribution of civets meant that the determined effective area covered by each grid would likely be an overestimation, thus reducing density. Another method that could have been used to determine *V. tangalunga* population density instead of using SECR would have been to determine the abundance of the species by applying several models available in the program MARK to a capture history matrix calculated for each grid. Separately, an estimation of the effective area sampled by the grid could have been established via constructing a polygon around the camera trapping grid, accounting for a buffer zone beyond the extent of the camera trap array itself as well as hard spatial boundaries. Using the resultant abundancy estimate (n) in conjunction with the estimated area (A), it would have been possible to manually derive a population density value with the equation:

$$D = n / A$$

In conclusion, this survey suggests that *V. tangalunga* are present throughout the LKWS yet not as abundantly as other areas, particularly of primary forest type. Nonetheless, this study in conjunction with other research concerning their population status assures that the species is not highly threatened.

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