Malay civet (*Viverra tangalunga*) sleeping site selection in the degraded and human-modified Lower Kinabatangan

Jessica Shuttleworth

Biological Science BSc

Vocational Supervisor: Dr Benoit Goossens

Danau Girang Field Centre

Cardiff University

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Contents

Abstract

The Malay civet (*Viverra tangalunga*) plays a vital role in Southeast Asia's ecosystem both in seed dispersal and rodent control but they can also act as an effective indicator species due to their generalist behaviours. By investigating their sleeping sites (an essential component of any species' habitat) and extrapolating the core requirements for sleeping locations both in secondary forest and oil palm plantations we can begin to understand if the human modified landscape found in the Lower Kinabatangan Wildlife Sanctuary is suitable for this species and how well adapted these animals are to a changing environment. To help identify what *V. tangalunga* select for when choosing a sleeping site and whether there are any differences in this selection in different human modified environments this study used data collected from seven satellite collared male Malay civets who were utilising both degraded forest and oil palm plantations, they gave us the GPS locations of 1053 sleeping sites. Of these sites, 70 were visited (10 from each collared civet) as well as 70 randomly selected 'unused' sited from within the civet's home ranges. At all 140 sites habitat surveys were carried out, measuring various environmental variables such as canopy cover, ground cover and understory density to give an idea of what the civets are selecting for and what makes a suitable sleeping site. This data was analysed using Generalised Linear Mixed Models (GLMM) with binomial error and logit link, using a binary response variable representing sites used by civets (status = 1) and randomly generated sites representing available 'unused' sites within the civets' home range (status = 0). The model showed that civets are selecting for dense understory density, proximity to water and sites that are near the boundary between forest and plantations. Separate modelling of forest and plantations also suggested that forest provides more suitable habitat while plantation sleeping sites tend to be located in remnant forest areas or in long grass (>50cm). With these findings we are not only improving our knowledge of this species, but we can provide suggestions for plantation management to make improvements that will benefit civet populations.

1.0 Introduction

Civets (*Viverrdae)* are an integral part of Southeast Asia's ecosystem (Jennings et al 2009). Being one of the more abundant and diverse small carnivore species they are of vital ecological importance, mainly in seed dispersal and rodent control (Colon, 2006). The Malay civet (*Viverra tangalunga*) (Figure 1) is a commonly seen terrestrial small carnivore species found in logged and secondary forest. Specifically in the lower Kinabatangan, it was the most abundant species seen in the longest running camera trap survey (November 2010 - May 2015)(Evans, Vickers and Abu-bakar, 2011) and is regularly seen throughout the lowlands and hills across Borneo (Phillipps, 2016). However, even though the ecological importance of this species has been recognised, there have been very few studies on its natural history and ecology (Jennings et al, 2009). The paucity of spatial ecology and biological requirement data in all small carnivores but especially the Viverrdae family can be attributed to the fact that it has, up until this point, been extremely difficult to acquire any satellite tracking data due to bulky and heavy collars (Evans and Guerrero-sanchez, 2016). However recent developments have allowed GPS collars to become lighter and smaller meaning a deeper understanding and knowledge of these animals can be obtained which is essential for future protection and conservation.

The Malay civet (*V. tangalunga*) (Figure 1) is of particular importance as they are a generalist species feeding on a variety of different food groups, ranging from rodents, invertebrates, birds, snakes and lizards as well as fruits, especially figs (Colon and Sugau, 2012). While it has been seen that their fruit consumption is reduced in logged forest compared to primary forest due to reduced number of fruiting trees, this may be offset by increased consumption of insects (Colon and Sugau, 2012), or the consumption of oil palm fruit when presented with oil palm plantations. This opportunistic approach to feeding allows this species to be more adaptable to changing environments and this has been seen in their ability to utilise oil palm plantations for feeding and for resting. This also means that they can be used as an indicator species for environmental health, if civets start to show signs of decline then this would imply the ecosystem as a whole is deteriorating. Due to the fact that *V. tangalunga* seem to be one of the species feeding on the vastly abundant oil palm fruits in the plantations, they can also be used to investigate the ecotoxicology, to see if these plantations are having adverse effects to the animal's health.

Figure 1. Camera trap (Reconyx) image of *V. tangalunga* taken in the Lower Kinabatangan Wildlife Sanctuary by Danau Girang Field Centre

Whilst *V. tangalunga* is such an important member of the Southeast Asian ecosystem and seems to be relatively abundant they still face various threats. The main threat to our planets wildlife as a whole at present is habitat loss which is happening on a global (Sodhi and Brook, 2006; Edwards *et al.*, 2014; Costantini, Edwards and Simons, 2016) scale at an alarming rate. For the Malay civets who is found in Peninsular Malaysia, Sumatra, areas of the Philippines and across Borneo in lowland and wetland forests (Jennings, Zubaid and Veron, 2010), the most pressing threat is habitat loss through conversion to oil palm plantations.

Palm oil is the world's most rapidly expanding crop and already accounts for ~1 tenth of global perminant cropland. (Koh and Wilcove, 2008), this expansion is concentrated specifically in Malaysia and Indonesia were over 80% of the worlds palm oil is produced (Fitzherbert *et al.*, 2008) the knock-on effect of this being that these areas are faced with the highest rates of deforestation the world has ever seen (Fitzherbert *et al.*, 2008; Koh and Wilcove, 2008; Evans, Vickers and Abu-bakar, 2011). This causes great concern for our planets wildlife as these countries are also home to 11% of the worlds remaining tropical forest containing large numbers of rare and endemic species (Koh and Wilcove, 2008). In Malaysia alone over 1 million ha of forest has been converted to oil palm between 1990-2005 (Fitzherbert *et al.*, 2008; Koh and Wilcove, 2008) a large proportion of this has taken place in the lowland forest of Borneo and although rainforest covers ~50% of this tropical island, most of this is found in the central montane region (Scriven *et al.*, 2015). The lowland forest of Borneo contains the majority of vertebrate species and has been highlighted as critically important priority region for small carnivore conservation, in addition to this, 50% of endemic birds and 35% of endemic mammals depending on lowland forest thus further deforestation in these areas has cause for high conservation concern (Evans, Vickers and Abu-bakar, 2011; Scriven *et al.*, 2015).

Although deforestation and conversion to oil palm is an obvious and immediate threat to biodiversity (Sodhi and Brook, 2006) a secondary concern caused by this land use change is the fragmentation of the remining forest. The large expanses of inhospitable agricultural land acts as a barriers to dispersal and can reduce gene flow as well as preventing populations from tracking climate as it changes which can result in extinction (Fitzherbert *et al.*, 2008; Scriven *et al.*, 2015). This fragmentation also exposes larger expanses of previously isolated areas to human populations. With increased proximity the risk of conflict between wildlife and humans is amplified. Malay civets being opportunistic predators, will start to encroach into human occupied areas in search of scraps and prey such as domestic chickens. This means while civets are not usually actively hunted they are in danger of being caught and killed if they start becoming problematic (Jennings, Zubaid and Veron, 2010). The increase in infrastructure, especially roads will also act as a further barrier to dispersal and can increase mortalities in the form of road kill.

Sleeping sites are an essential part of any species habitat and are hypothesised to integrate key component of an animal's habitat by provide thermoregulatory benefits, protection from predators, proximity to prey and secure locations for consuming prey (Aubry, K. B. et al. 2013). While it has been seen that *V. tangalunga* sleeping site are usually found on ground level and associated with well drained terrain, protected by some form of cover whether it be fallen trees, vine structures or thick herbaceous vegetation (Colón, 2002) there have not been any focused studies specifically looking at sleeping site selection, especially in the LKWS. The ability to identify selection for sleeping sites for this species will potentially allow us to predict locations of resting sites which can then help with management and future conservation. To increase knowledge of choice of sleeping sites this study will look at environmental and spatial factors as well as specific structures that may influence sleeping site selection. By looking at the sleeping site selection of *V. tangalunga* we hope to extrapolate the core requirements for a sleeping site looking in both secondary forest and oil palm plantation habitats. It is in the comparison between the two different ecosystems that we will be able to identify if the plantations and human modified areas are a viable habitat for this species.

2.0 Methods

2.1 Study area

This study took place in the Lower Kinabatangan Wildlife Sanctuary (LKWS) which consists of ~270km^2 area of protected secondary forest split into 10 distinct plots with varying levels of connectivity. The plots are made up of dry lowland, semi-flooded, and swamp forest with small areas of grassland (Evans, 2016)(Evans *et al.*, 2017). The Kinabatangan is the longest river in Borneo and is located in eastern Sabah, Malaysia, Borneo. In this tropical area with a humid climate temperature ranges from 21-34°c with an annual rainfall average of 3,000mm (Evans, Vickers and Abu-bakar, 2011)(Abram *et al.*, 2014). This natural landscape however, has been severely impacted by past commercial logging and forest conversion associated with the spread of agricultural oil palm. The majority of the remaining forest is fragmented or surrounded by oil palm plantations (Abram *et al.*, 2014) in which some of this research takes place.

2.2 Satellite Collaring

The GPS data used in the study was acquired using the results collected from the first known satellite collaring of a viverrid species by Evans and Guerrero-Sanchez (2016). Trapping of the individuals took place between October 2013 – August 2015. Over the 731 active trap nights (number traps x trapping nights), 43 small carnivores were successfully caught. From these captured, 27 were unique Malay civet (*Viverra tangalunga*), of which 9 were successfully collared. From these collared animals, data was successfully retrieved from 7 individuals. These individuals are the subject of this study. Each civet was collared with Collar 1A or second-generation Collar 1A (e-obs GmbH, Grurünwald, Germany), containing GPS microchip, either 2300 or 2500 mAh battery, UHF radio transmitter, tri-axial accelerometer and an antenna. The collars were designed to drop off through thin section of leather near fastening (Evans and Guerrero-sanchez, 2016). The collars were set to record 13 hourly GPS fixes from 1800h to 0600h. With a field success rate of 58.1%, 4906 successful fixes were achieved.

2.3 Identifying Sleeping sites

The term ‘Sleeping site’ is defined here as where the animal spent the day resting. Civets are nocturnal animals (Colón, 2002; Jennings, Zubaid and Veron, 2010) with 79-82% of their activity taking place between 1800h and 0600h (Colón, 2002) and therefore only the 1800h and 0600h GPS fixes were relevant when looking for potential sleeping sites as all other fixes occurred while the animals were active. From the seven individuals being studied there were a total of 953 successful fixes in the time span from1800h and 0600h between October 2013 - 2017. As we had more successful fixes (510 GPS points) at 0600h and thus more data to work with, it was decided these fixes should be used as the sleeping site locations. Of these 0600h fixes, 271 are found in the forest and 239 are found in plantations. The same number of random un-used sites also needed to be measured in order to look at selection. The unused random points were selected using 95% MCP home range polygon and the Arc function ‘select random point’. Due to time and logistical limitations it was not feasible to visit all 1020 sites. Therefore, for each individual, 10 used sites were randomly selected (while maintaining the same ratio of forest:plantation) and 10 unused sites from within the home range with the same ratio. In total, n=140 sites (combined used and

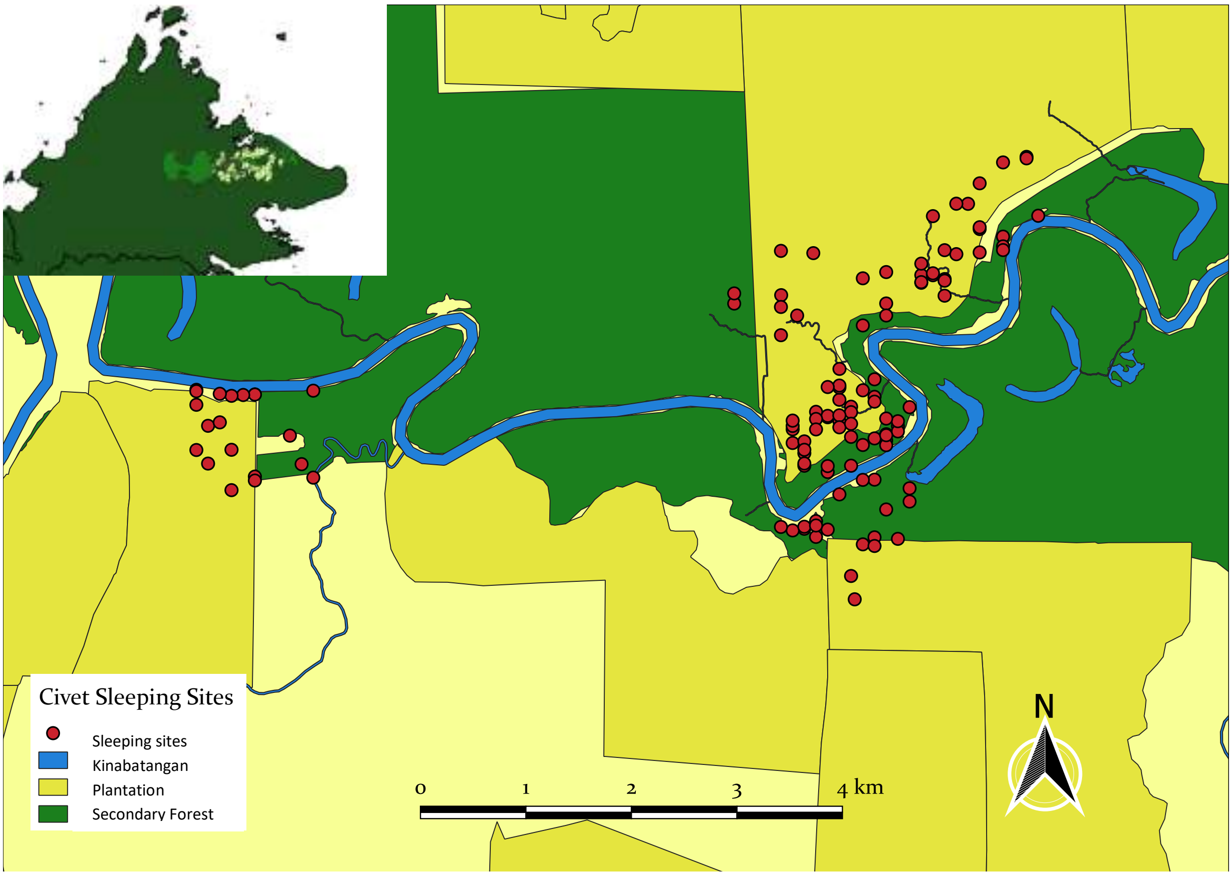

Figure 2. Map showing all sites visited, combination of used sleeping sites (n=70) and randomly selected sites (n=70). Found in the Lower Kinabatangan Wildlife Sanctuary and surrounding oil palm plantations. Top left shows location of LKWS within Sabah.

random sites) were used for this study as seen in figure 2. The sample size chosen still favours the idea that analytical rigor is strengthened more so by an increase in the number of individuals than the number of locations per individual. During field work some of the site were inaccessible for several reasons including impassable swamps, drainage ditches and killer bees. In the case of inaccessible sites, if it was a random unused location, a new location was chosen 100m North of the original site. For the inaccessible used sites, a new position was randomly selected from the remaining satellite collar data.

2.4 Ecological Survey

Sleeping sites were located in the field using a handheld GPS (Garmin). A central quadrat was thrown when the sleeping site was reached, from there a 10x10m plot was established, measuring 7.07m towards each compass point, each corner was marked with tape. Once the plot was established, measurements were taken from each corner and from the centre point. These include ground cover (%) and ground cover depth (within 1x1m^2 quadrate) (Table 1). Understory density was measured at knee and chest height using an Understory Density Stick (UDS), a striped stick measuring 1.7m in length with 50 equally spaced stripes. The UDS was held horizontally to give targeted slice of vegetation structure at understory (knee/ civet height) and mid-story (chest height). A photograph of the UDS was taken from the central point with the UDS in each corner and then from the north point with the UDS in the centre. From these photographs, the number of stripes were counted and from this a measure of the density was gained as a percentage. Canopy cover is measured using pictures taken of the canopy at chest height in each corner and at the centre then later analysed using ImageJ to give a percentage.

Once these measurements have been taken the number of different sized trees were counted. A subjective score (0-5) was given for the number of vines and saplings present to give a further idea of the vegetation density of the site. For sites in the plantation, the vine score is substituted for a fern/epiphyte score. Additionally, any logs, tree cavities or hollows that could potentially be used as a sleeping site are noted. Any potential sleeping sites above 3m were discarded as *V. tangalunga* are non-arboreal and do not tend to utilise the upper canopy (Colón, 2002). Further, the canopy height is measured by identifying the three tallest trees then using a clinometer to attain an angle and trigonometry to work out the height. Using the program QGIS (QGIS Development Team 2019) the distanced from water bodies (river, tributaries and oxbow lakes) and from the edge of the forest/plantations were measured to identify if there is an edge effect influencing selection. The same environmental and spatial measurements were taken for points located in plantations but with the addition of the age of the plantation and the distance of the sleeping site from the closest large/main road (used by vehicles).

Table 1. List and description of variable measured to analyse sleeping site selection for the Malay civet (*V. Tangalunga*)

Variables	***Description***
Ground cover	*Cover of vegetation as a percentage in a 1m^2 quadrate*
Groundcover depth	*Height of vegetation within 1m^2 quadrate*
Understory Density	*Measurement of density using UDS at knee height*
Midstory Density	*Measurement of density using UDS at chest height*
Canopy Cover	*Measurement of coverage using program ImageJ*
Canopy Height	*Average height of three tallest trees*
Vine Score	*Subjective sore based on the density of vines and presence of dense vine structures (measured in forest only)*
Epiphyte Score	*Subjective score base on density of epiphytes (only measured in plantation)*
Hollow Logs	*Presence of hollow logs large enough to be used as a sleeping site (hole with a diameter >40cm)*
Tree Cavities	*Cavity within tree or buttress roots large enough to be used as a sleeping site and <3m off the ground*
No. Large Trees	*Number of trees with a diameter at breast height >40cm*
No. Medium Trees	*Number of trees with a diameter at breast height between 10-40cm*
No. Small Trees	*Number of trees with a diameter at breast height between 5-10cm*
Sapling Score	*Subjective score given for the number of saplings (young trees with a diameter at breast height <5cm)*
Distance from Edge	*Shortest distance from sleeping site to the nearest boundary between forest and plantation*
Distance from Water	*Shortest distance from sleeping site to nearest water body (river, tributary or oxbow)*
Distance from River	*Shortest distance from sleeping site to the Kinabatangan River*
Distance from Tributary	*Shortest distance from sleeping site to nearest tributary*
Distance from Oxbow Lake	*Shortest distance from sleeping site to nearest oxbow lake*
Distance from Road	*Shortest distance from sleeping site to nearest main road used by vehicles (only measured in planation)*
Plot age	*Age of plot at time of measuring variables (only measured in plantation)*

2.5 Analysis

Selection of sleeping sites by Malay civets - To determine if *V. tangalunga* are selecting for any particular environmental attributes, specific structures (hollow logs, tree cavities) or spatial attributes (only variables measured in both forest and plantations habitats, Table 1) a Generalised Linear Mixed Model (GLMM), with binomial error and logit link was fitted using a binary response variable representing sites used by civets (status = 1) and randomly generated sites representing available 'unused' sites within the civets' home range (status = 0). Individual civet data was nested into the model as a random effect to help eliminate pseudo-replication. The final model was achieved using single term deletion, removing variables that had no significance. McFadden's pseudo-R2 was used to test goodness of fit. GLMM's were fitted using the package lme4 (Bates, Maechler and Bolker, 2013) and all analysis was completed using the program R Studio (R version 3.3.1 (2016-06-21) -- "Bug in Your Hair")

Sleeping site selection with the forest – A Generalised Linear Mixed Model (GLM) with binomial error and logit link was fitted using data collected from just the forest sleeping sites with used (status=1) and random (status=0) sites coded as binary variables to determine selection within protected forest habitat. The individual civets were nested into the model as a random effect to help eliminate pseudo-replication. All variables in Table 1 measured in the forest were considered the model was then fitted using single term deletion. McFadden's pseudo-R2 was used to test goodness of fit. GLMM's were fitted using the package lme4 (Bates, Maechler and Bolker, 2013).

Sleeping site selection with the plantation – A Generalised Linear Mixed Model (GLM) with binomial error and logit link was fitted using data collected from just the plantation sleeping sites with used (status=1) and random (status=0) sites coded as binary variables to determine selection within oil palm plantations. The individual civets were nested into the model as a random effect to help eliminate pseudo-replication. All variables in Table 1 measured in the plantation were considered, the model was then fitted using single term deletion. McFadden's pseudo-R2 was used to test goodness of fit. GLMM's were fitted using the package lme4 (Bates, Maechler and Bolker, 2013). These smaller models give an insight into any selection within the distinct habitats.

3.0 Results

Seven male Malay civets were collared and provided GPS information, from this data 64% (n=93) of sleeping sites where found in forested areas while 36% (n=51) were found in the plantation. Of the used sleeping sites the majority (n=66, 90.28%) revealed no obvious structures (tree hollows or hollow logs) that could have been used for resting suggesting the civets where using other environmental features to provide protection. During data collection it was noticed that long grassed areas where common, this was represented by the fact 50% (n=35) of all used sites had a substantial amount of grass measuring over 50cm and 61.54% (n=16) sleeping sites found in plantations had long grass present.

Selection of sleeping sites by Malay civets – A Generalised Linear Mixed Model (GLMM) showed that used site are significantly different from randomly selected sites within the civets' home range, thus suggesting there is some form of selection. Of all the features measured (Table 1) it can be seen in Table 2 that civets are selecting for sleeping sites that have higher understory density, less mid-story density, close to water bodies and close to the edge where plantation and forest meets. McFadden's pseudo-R2 gave an R^2 value of 0.13. Thus, while this model does not show an excellent fit a higher value is not expected with this data. However, it still signifies there is evidence of a relationship between these variables and Malay civet sleeping sites.

Table 2. Statistical analysis (GLMM) showing selection for sleeping sites for *V. tangalunga* within the LKWS.

Fixed Effect	Pr(>|z|)	Std. Error	Selection
Understory	0.000414	0.013971	+
Midstory Density	0.004413	0.013131	-
Distance to Edge	0.021686	0.001149	-
Distance to Water	0.021942	0.000905	-

Sleeping site selection within the forest – When analysing sleeping sites found in the protected forest within the Lower Kinabatangan Wildlife Sanctuary the GLMM suggested that ground depth and midstory density were significant for *V. tangalunga* when selecting a sleeping site (Table 3). However, this model has a low McFadden's pseudo-R2 value (0.077).

Sleeping site selection within plantation – The GLMM for plantation data suggested that Malay civets show some form of preference in areas that have higher levels of ground cover, more canopy cover and further away from the edge of the plantation (Table 3). The McFadden's pseudo-R2 value for this model showed an excellent fit with a value of 0.35.

Table 3. Statistical analysis (GLMM) showing selection for sleeping sites for *V. tangalunga* in two different habitat types (forest and plantation)

	Fixed Effect	Pr(>|z|)	Std. Error	Selection
Forest	Ground Depth	0.00842	0.01779	+
	Midstory Density	0.04839	0.01102	-
Plantation	Ground Cover	0.00224	0.028813	+
	Canopy Cover	0.04768	0.017302	+
	Distance to Edge	0.01340	0.004392	+

4.0 Discussion

4.1 Sleeping site selection

In the lower Kinabatangan wildlife sanctuary, it seems male Malay civets are selecting sleeping sites along the edges between forest and plantation while keeping a proximity to water bodies in areas with dense understory but more open mid-stories. These findings support the idea that civets sleeping site are associated with dense cover/ vegetation (Macdonald and Wise, 1979; Colón, 2002; Jennings, Seymour and Dunstone, 2006; Jennings, Zubaid and Veron, 2010b; Evans, Vickers and Abu-bakar, 2011; Colon and Sugau, 2012; Evans and Guerrero-sanchez, 2016) but also suggests that this cover comes from understory foliage (<50cm) which also make sense as *V. tangalunga* sleeping sites are also usually found at ground level (Colón, 2002; Jennings, Seymour and Dunstone, 2006; Jennings, Zubaid and Veron, 2010b; Ross *et al.*, 2016). While modelling showed that distance to a water body is significant when it comes to sleeping site selection, what is interesting is there is no preference for a particular type of water body. The main river, tributaries and oxbow lakes were represented as separate factors in the model, but none are significant on their own.

Our model also suggested that *V. tangalunga* show preference for sleeping sites closer to the edge of the plantation/forest depending which habitat the civet is resting in. This suggests civets respond to an edge effect which supports the idea civets are highly adaptable (Colón, 2002; Jennings, Seymour and Dunstone, 2006) and can thrive in a human modified environment. This also suggest they are utilising the plantation for hunting and foraging due to the fact it is hypothesised that sleeping site are generally found in proximity to feeding areas (Aubry *et al.*, 2013; Aubry, Raley and Cunningham, 2018). This also make sense as it has been seen that because of their extremely opportunistic behaviour civets will adapt their diet based on the abundance of prey or fruit (Colon and Sugau, 2012). In secondary forest where there is less fruit they eat more insects from this we could assume if there is an abundance of fruit available in the plantations they will eat more fruit. While Colón (2002) suggest that trails and roads are an important resource for this species, especially males, it seems that proximity to roads does not impact sleeping site selection However, this may explain why *V. tangalunga* are utilising the oil palm plantations as they have a well-established network of roads that could make travel easier but also increase the likelihood of encountering prey and fruit.

When the two distance habitats were separated the GLMM's showed different variables were significant depending if the sleeping site was found in the forest or the plantation. Because the fit of the forest sleeping site model was poor this suggests that these variables had less of an effect on the selection and thus suggest that the forest habitat provides greater choice of usable sites. In other words, most of the available sites within the civet's home range can be used as a sleeping site. However, it could also mean that the variables that were measured were not significant, but selection may be based on variables that were not measured. The model fitted to the plantation data showed high discrimination ability and so it seems we can say with a certain amount of accuracy that ground cover, canopy cover and distance from the edge are associated with sleeping site selected by Malay civets in oil palm plantations. The fact that civets seem to be selecting for higher canopy cover in the plantation supports the idea that the forest provides suitable habitat as the mean canopy cover across all forest sites (70.27%) measured was significantly greater than that seen in the plantation (53.39%).

The majority of sites (n=20, 76.93%) within the plantation were found within remnant forest or in long grass (>50cm). This therefore represents a very important feature within plantations that are vital for civet sleeping sites. It stands that the long grass would provide the necessary understory density and sufficient ground cover while the remnant forested areas are vital in providing adequate canopy cover. These findings provide incentive to protect or promote these types of habitats within the oil palm plantations. However, the fact that civets are relying on these kinds of microhabitats within the plantations suggest that they may not be a well-adapted to human modified environments as we originally believed. This is supported by the fact that although they seem to be relatively abundant, Meijaard et al (2008) discovered that Malay civets are one of the many species to be severely impacted by selective logging, suggesting they are not as robust of a species as they seem.

While the model using data collected from all sleeping sites shows civets are selecting sites in close proximity to the edge of plantations the smaller model looking at just sleeping sites within the plantation shows preference for site with a greater distance from the edge of plantation. This may suggest that the edge effect is having more of an effect on sites found in the forest. This could also be explained by the fact that the randomly selected points were selected from a 95% MCP home range and this home range rarely extended deep into a plantation and so all 'available' locations were relatively close to the forest/plantation boundary. And while a 95% MCP home range estimator is not very informative or powerful for advanced spatial ecology, it was suitable for selecting random point as it provides a conservative estimate of where the individual civet could potentially sleep.

4.2 Limitations

Satellite collaring for this study took place between October 2013-August 2015 whereas the habitat data was collected between November 2018-April 2019 thus there is a 3-6year gap between a civet utilising an area as a sleeping site and the habitat being analysed. Due to the ever-changing nature of the habitat this leads to some limitation to this study. While the general attributes of the habitat should stay relatively stable exact feature will have likely changed during this time frame. This is particularly prominent for one of the individuals who was utilising a restoration plot along the edge of a newly planted plantation. While it is difficult to rectify this limitation, it has been noted and also prevented any attempt at identifying specific microhabitat used by the Malay civet as these are more likely to change.

GPS error of both the collars and our handheld devises will have played a role in causing error within this study. This was considered when selecting a 10x10m plot around the GPS point rather than a more focused analysis of a specific resting place. This error meant that a specific resting place could not be identified and thus just a more general sleeping area was analysed. Future studies wanting to identify specific resting structure or microhabitat will need to use VHF and try and get a visual of the animal when tracking. However, this involves more intensive fieldwork and would result in fewer sleeping sites being identified in a similar time frame as tracking may not always be successful. Other limitations have been discussed by Evans and Guerrero-Sanchez (2016). GPS error should be relatively consistent for every sleeping site and thus should not impact statistical analysis.

Within the methodology measurements of vines, epiphytes and saplings were obtained using a subjective scoring system (0-5), this may have its draw backs due to the fact that, especially at the start of data collection, it was difficult to identify each level. However, to counteract this subjective nature consistency was maintained for every site as I was the one to provide the sore. Furthermore, during pilot studies and for the first few months of data collection, photos were taken of each site, so they could be compared to other sites to ensure scoring was constant across all sites.

4.3 Implications and future studies

Habitat selection has become an essential tool in conservation and wildlife management but it encompasses several hierarchical levels (Camps and Alldredge, 2013) and in order to implementing effective conservation methods there is need for future studies to investigate the next level of the hierarchy selection and identify if Malay civets require specific resting structures or micro habitats. With current GPS error as formerly mentioned this would most likely have to involve VHF based tracking in order to gain the proximity needed to acquire a visual of the animal to identify specific microhabitat being used. There may also be other factors influencing sleeping site selection such as proximity to prey.

Once this has been established one could then go onto investigate the relationship between civets in plantations, rodent control and the effect they might have on the yield of oil palm. Having this information and essentially placing a value on the civet can then provide a greater incentive to modify plantation management to make more civet friendly corridors through a plantation. With our current findings it seems the most effective corridors would ideally include forested areas or areas with grass exceeding 50cm in height. However, in order for change in management to be successful it must be done in tandem with education programs. It has been suggested by Jennings (2010) that mortality rates of civets are higher in or near plantations which may arise from an increase in conflict. From personal observations plantation workers have negative views of civets as they are known to steal domesticated chickens. For civet friendly corridors to work these workers would have to have some incentive, this could come from improved rodent control but additionally it would be beneficial to provide education on how to better protect livestock to encourage a more harmonious lifestyle. In addition to creating corridors it would also be beneficial to protect remnant forest already present in plantations especially those located relatively close to the plantation edge. Our data suggest that civets are utilising these types of habitats up to ~700m from the edge of the plantation.

Conclusion

Malay civets are a relatively adaptable species who seem to be selecting for sleeping site close to the edge between plantation and forest while also maintain proximity to a water body in areas with dense understory. Although they are utilizing the plantations, this edge effect suggest that their adaptability is not as strong as it seems, they still need forested areas and are reliant on remnant forest and long, overgrown grassy areas within plantations. However, future management and education programs could lead to a more civet friendly environment.

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