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Activity Patterns and Behaviour of Denning Dholes (*Cuonalpinus*) in a Dry Deciduous Forest of East Java, Indonesia

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ABSTRACT
We conducted the first research on the activity patterns and movement of denning dhole in the Baluran National Park, Indonesia. Camera traps and radio telemetry surveys were employed to observe dhole activity patterns and movement over the denning period. The dholes showed crepuscular and diurnal activity patterns with most activities intensifying at dawn and dusk, and becoming less intense in the middle of the day. The dhole's home range comprised of hunting grounds, water resources, and a den in the centre. The home range size was estimated at 744.86 ha (using the 95% Minimum Convex Polygon/MCP method), at 1418.28 ha (using the 80% Kernel Utilization Distribution/KUD analysis), and at 479.59 ha (using 90% Local Convex Hull/LoCoH), whereas the core area was estimated to be 636.36 ha (50% KUD) and 67.37 ha (50% LoCoH), and the size of the most greatly used area at 231.57 ha (25% KUD) comprising of the den sites and the hunting grounds. The dhole's den ecology strategy was to use other animal's burrows on steep slopes with dense vegetation cover and located on the opposite side of the hill to where human activity occurred. Den switching occurred every 2 weeks. These results indicate that dholes selected a den site that fulfilled their needs for food, water, cover, and predator evasion.
Keywords: *Cuonalpinus, den ecology, radio telemetry, home range, predator.*

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INTRODUCTION

Habitat use by individual animals can be influenced by various factors. Generally speaking, individuals will select habitat that will maximize their fitness in relation to their activities [1]. For many carnivorous mammals, dens are an essential component of their life history and may act as a limiting factor that will affect their abundance and distribution [2, 3].The access to a den is therefore essential for carnivores in terms of successful breeding and cub rearing [1, 4, 5]. Site selection surrounding dens can therefore be said to influence den use, because it could affect safety from predators and access to food resources [3]. Therefore, the availability and use of denning sites are important aspects in the ecology of most canids and indicative of breeding units within the habitat [5, 6] and consequently a valuable aspect to be considered in species management [7].

The dhole (*Cuonalpinus*) is an elusive endangered predator that inhabits Asian jungle. Similar to their relatives – wolves (*Canis lupus*) [8] and African wild dogs (*Lycaonpictus*) [3], dholes breed once a year and raise their pups in dens [9, 10]. The pups are suckled until at least 58 days and stay around the den site until they are 70-80 days old [9]. Their dependence on these denning sites makes the denning period the dholes' most critical and vulnerable time [9]. Hence, if one is to support the management and conservation of this species, it is important to have a good understanding of their ecology during the denning season (including information about denning ecology and home ranges). Knowledge about den ecology is crucial for understanding the denning strategies of targeted species in given environments, ultimately leading to reproductive success [1, 3, 5-7]. Knowledge about home ranges on the other hand is also crucial to understand how much space is required, which kind of habitat is necessary, and the effects of various factors (e.g. food resources and breeding requirements) on spacing behaviour and movements

during the denning season [11]. This kind of knowledge could make a significant contribution towards the future management and conservation of dholes both in the wild [9, 10] and in captivity [12, 13].
In spite of its importance, scientific information about the ecology of dholes during the denning season in the wild is limited. Fox (1984) reported the denning ecology of dholes in south-western India which emphasized the den structures. He described four different types of dens, namely: 1) a simple earth den with one entrance, 2) a complex cavernous earth den with more than one entrance, 3) a simple cavernous den excavated under or between rocks with one entrance, and 4) a complex cavernous denning area with several dens in the same vicinity, some of which may interconnect. Frequency of interaction and behaviour shown towards the pups in the den by individuals of varying ages and sex were found to be significantly different, with males showing a higher frequency compared to females [10]. Cooperative care of young dholes by males appears to arise as a consequence of confused paternity, when more than one male has access to the female, or as an intention to appease the dominant male and remain in the pack [10]. We carried out the first study on activity patterns and movement behaviour of denning dholes (*Cuonalpinus*) in the Baluran National Park (BNP) on East Java in Indonesia. In this paper, we discussed the denning ecology of the dhole including den characteristics, daily activities while denning and their movement patterns over the denning period.

METHODOLOGY

This research was conducted in the Baluran National Park (BNP) on the island of Java in Indonesia. It is located in the northeast of Java with the bearings 70029'10'' to 70055'55'' S and 113029'10''-113039'10'' E, covering c.a. 25,000 ha. The park is bordered by the Bali Strait to the east, the Madura Strait to the north, and the Bajulmati and Klokoran Rivers to the south west of the park. The BNP has a typical monsoon climate with a long dry season from April to November and most precipitation from December to February [14]. During the driest months (August-November), precipitation tends to be close to zero [15]. Elevations in the BNP landscape range from 0 in coastal areas in the northern and eastern parts of the Park to 1,268 above sea level at the peak of Mount Baluran in the middle of the park [16]. For management purposes, the BNP was divided into two management sections, namely section I Bekol, which consists of the Bama Resort, the Balanan Resort, and the Parengan Resort, and section II Karangtekok, which consists of the WatuNumpuk Resort, the LabuhanMerak Resort, and the Bitakol Resort. The habitat types found in this park are coastal forest, mangrove forest, temporary wetland, savannah, shrubland, primary forest, secondary forest, *Acacia nelotica* stands, managed forests, and settlements. Large herbivores inhabiting this park include banteng (*Bos javanicus*), buffalo (*Bubalus bubalis*), Javan deer (*Rusa timorensis*), Indian muntjac (*Muntiacus muntjak*) and wild boar (*Susscrofa*), with the only large carnivore other than the dhole being the leopard [15].
The dholes' den sites were identified using ground surveys during two observation periods: September 2013-January 2014 and August-September 2014. Dens were identified, by visiting locations that could potentially be used as dens by dholes i.e. hilly areas, dry creeks, and cliffs [9]. A den was classified as being active when the den was inhabited by dholes. Once an active den had been identified, we installed camera traps (Bushnell NVW HD) in front of the den to observe the activity patterns of denning dholes. Each activity was recorded at one hour intervals over 24 hours during a 38-day observation period (18th August – 24th September 2014). We calculated the frequency of each activity occurring to identify the pattern with the formula $ni*100/N$, where ni is the number of activities (e.g. feeding or playing) detected during a certain time interval and N is the total number of activities I over all time intervals. We recorded the den and the characteristics of the vicinity i.e. entrance direction, number of entrances, height and width of entrance, and den depth using a 0.04 ha circular plot. The characteristics of the den's vicinity included the distance of the den from the nearest water resource which was measured by QGIS 2.8.2 Wien (Quantum GIS Development Team 2015), the canopy closure and the ground cover (recorded using an ocular tube in two cardinal directions), slope which was measured using a clinometer (Suunto Tandem-360PC/360R G Clino/Compass, Vantaa, Finland), surface component (substrate) i.e. soil, rock, leaf litter, and decayed wood which were measured by four 1x1 m plots situated in four cardinal directions within a radius of two meters from the den's entrance, and vertical cover density which was measured using a density board. All procedures used to measure the characteristics of the den's vicinity were carried out by following the sampling protocol procedure [17].
Movement patterns were recorded by radio telemetry, using a 120 gram radio collar at 148-151.999 Mhz, Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA) and a GPS logger (i-gotU GT-120, Mobile Action Technology, Inc., New Taipei City, Taiwan) [18]. Telemetry has enhanced the ability of wildlife ecologists to locate animals, increasing the opportunities to examine detailed ecological and management questions that are related to animal movements, animal behaviour, habitat use and activity [19]. In order to capture the dholes, from the end of November 2013 to early January 2014, 5 steel box traps [20] were

installed with various baits (fresh beef meat, deer carcass, live duck, and live monitor lizard) and 5 snare traps were set up at locations that were potentially visited by dholes. Camera traps (Bushnell NVW HD) were also installed at the locations where the traps had been set up to establish the efficiency of each trap. None of the traps were found to be effective for capturing dholes in the BNP, due to the presence of other scavenger species (i.e. common palm civets (*Paradoxurus hermaphroditus*) and monitor lizards (*Varanus salvator*)) that were caught in the traps before the dholes. For the second period of data collection (August – November 2014), 6 units of Duke #3 Rubber Jaw Coil Spring Traps 0474 traditionally used for beavers, foxes, bobcats, coyotes and wolves were used to capture dholes. The traps were set up along the path frequently used by dholes without using any bait, with the best path located close to the active den. This method was successful in capturing one male. The captured dhole was immobilized using a combination ketamine HCL and xylazine HCL following the procedure suggested by Acharya et al. (2010). The drug was directly injected into the buttock, after the dhole was handled using a Y stick to stop it from moving. During the immobilization process, the dhole did not show any signs of resistance, which was likely to be a result of fatigue after attempting to escape from the trap, so that the process was able to run easily and smoothly. The immobilized dhole was then weighed, sexed, radio collared and photographed.

The radio collared dhole was tracked every day from 18th August – 24th September 2014. The majority of the locations were obtained from the ground survey using a H handheld RA-14 VHF antenna (Telonics, Inc., Mesa, Arizona, USA) and an ATS R410 scanning receiver (Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA) during daylight hours 0700hrs – 1800hrs, using triangulation or by finding the dhole's resting area during periods of inactivity. At least once a week, we attempted to record the location at 1-hour intervals over 24-hour periods. The locations where the team located the radio-collared dhole were recorded using a GPS Garmin 78 CSX (Garmin International, Kansas, USA) and the bearings of the team to the dhole were measured using a compass (Suunto Tandem-360PC/360R G Clino/Compass, Vantaa, Finland). The actual location of the dhole was identified using QGIS 2.8.2 Wien (Quantum GIS Development Team 2015) with Triangulation 0.2.1. plugin (BorysJurgiel for Faunalia and University of Evora 2014).

The home range was estimated using the home range estimation method provided by R 3.2.0 software (R Development Core Team 2015) with the Ade habitat HR 0.4.12 package [21]. This home range estimation method included Minimum Convex Polygon/ MCP [22], Kernel Utilization Distribution/KUD [23], and Local Convex Hull/ LoCoH [24]. The use of a range of methods for home range estimates provides a meaningful comparison of home range size across studies [25]. MCP is considered as the simplest and most popular home range estimator, which draws the smallest convex polygon possible that encompasses all known or estimated locations for the animal [26-28]. This method has been criticized however, because a home range can include large areas of land which are never visited, and in some cased even impossible to access because of their geographical constraints [26]. However, because previous studies have used this method to estimate the home range of dholes [20, 29-31], we used the 95% MCP method in order to be able to compare our results to previous research findings. The KUD method was used to identify areas of high use, and is considered to be a method which provides a very good means of highlighting areas of concentrated activity [26]. Utility distribution could map the fitness that an animal gains from each place in its home range and the approach using utility distribution as a probability density function provides one objective way of defining an animal's normal activities [28]. The Kernel approach is highly sensitive to the choice of the bandwidth value [32], and we used 80% of the reference bandwidth (*href*) which is nearly unbiased for certain types of data [33] for home range estimation, 50% for the core range area [34] and 25% for the proportion of home range with the highest use [32]. In this home range estimation, we also used the LoCoH nonparametric kernel method which has been proven to be more appropriate than parametric kernel methods for constructing the home range and utilization distribution, because of its ability to identify hard boundaries (e.g. rivers, cliff edges) and convergence to the true distribution as sample size increases [24, 35]. LoCoH is a simple extension of MCP to a union of a set of local MCP [24] or generalizes the MCP method [35]. We used fixed k LoCoH with isopleths 90% range in estimating the area of the home range and 50% for the core area.

The daily range or daily distance travelled by the dhole over 24 hours was measured by summing the straight line distance between all consecutive locations over a 24-hour period [27]. In total, nine movement sequences were recorded and used in the analysis. The mean number of points used to produce the movement sequences was 3 (± 0.17 SE). The speed of movement of the radio-collared dhole was measured using a GPS logger which was installed together with radio telemetry [18].

RESULT

In total, 12 abandoned dens were identified during the first period of the survey, which were confirmed by the presence of old dhole scat at the location. In August 2014, based on our prior knowledge and the

assistance of experienced local people and rangers, we found three active dens which were later referred to as the den of the Bama pack, with 7 altricial pups with a sex ratio of 1:6. The dens were used by the breeding dholes consecutively whereby the first den was used by the female alpha to whelp, while the second and the third dens were used as temporary nurseries.

All active dens were located on hillsides — each one displaying a unique character (Table 1). All of the dens were excavated under rocks and the entrances were almost vertical. The nest had an entrance with a height of 40 cm, a width of 90 cm and a depth of 3.5 m. The distance to the nearest water resource was 338.4 m. The den was constructed on a steep slope (65%) with surface components that mainly comprised of sandy soil (51.25%) and rocks (30%). The canopy closure and ground cover in the vicinity of the den were 65% and 0%, meaning that the vicinity of the den had sufficient shade and was not covered by ground vegetation. The den had relatively high vertical cover densities at 0-300 cm (>60%), which can provide cover from predators i.e. humans and leopards. The characteristics of the second den were almost the same as the first den, and located on the same hillside, only 40 m away from the first den. The second den had one entrance and two chambers. Its size was bigger compared to the first den with a height of 50 cm, a width of 120 cm, and a depth of 3.8mand constructed on a steeper slope compared to the first den (70%). The surface components of the second den mainly comprised of sandy soil (61.25%) and rocks (25.75%). This den had a high canopy closure (70%) and very low ground cover (5%). The vertical cover densities were high at 0-200 m (>70%) and low at 200-300 m (32.5%), providing good cover for the den. A porcupine carcass was found close to the den and it is most likely that it was killed by the dholes when they took over its den. The third den was different compared to the first and the second den. This den was located 283 m from the first den and about 680 m from the nearest water resource. The den had three entrances and three chambers which were connected with one another. The den was constructed on a moderately steep slope (30%). The surface components mainly comprised of sandy soil (68.75%) and rocks (22.50%). The vicinity of the den had a low canopy closure (20%) and ground cover (25%). The vertical cover density at 0-30 cm, 30-100 cm, 100-200 cm, and 200-300 cm was 45.83%, 30.36%, 15% and 11.25%, respectively. The characteristics of the third den were likely to have been chosen by the dholes to facilitate active playing and socializing of the growing pups.

From the results of the observations, we divided dhole behaviour into 5 categories i.e. babysitting (adult individual staying with the young while the others foraged), inspecting (inspecting the pups in the den during the patrol activity), feeding (providing food), playing and grooming. The presence of an alpha female in the den was also recorded separately. Dhole activity was most intensive in the morning, evening and night, and less intense in the middle of the day (Figure 1). Babysitting mostly took place between 0300 and 0700hrs (29.41%), 2100 and 2400hrs (21.57%) and between 1500 and 1700hrs (15.003%), respectively. A similar pattern was also found for inspecting activities which mostly occurred between 0200 and 0600hrs (31.58%), between 2100 and 2400hrs (22.11%) and between 1700 and 1900hrs (16.84%), respectively, and also feeding activities which mostly occurred between 0500 and 0700hrs (36%), 2100 and 2400hrs (28%) and 1500 and 1700hrs (20%), respectively. Playing and grooming activities mostly occurred in the morning between 0300 and 0600hrs (45.45%) and between 0400 and 0800hrs (50%), and in the evening between 1600 and 1700hrs (18.18%) and between 1500 and 1700hrs (40%) respectively. The different patterns occurred for the presence of the alpha female, which intensively occurred from the night at 2200hrs until the morning at 0800hrs. The alpha female seemed to be absent in the den at 1700hrs, which is most likely to be the time she used to forage.

The dhole's home range size was estimated using 30 locations from the radio-collared dhole, which were separated by more than 5-hour intervals to avoid autocorrelation between locations [27]. This data was obtained from 38 days of tracking locations because the telemetry device was released after the collar was destroyed from continuous chewing by other individuals. It provided evidence that the radio-collared dhole was a subordinate member in the pack, so that its movement can be considered as a pack's movement. Based on the 95% MCP method, the dhole's home range size is 744.86 ha (Figure 2). This size is smaller compared to the male dhole's home range during denning in India, which was estimated to be 2550 ha [27]. The home range size based on the 80% KUD method was 1418.28 ha, while the size of the core area (50% KUD) and the highest use area (25% KUD) were 636.36 ha and 231.58 ha, consisting of 3 and 2 areas, respectively (Figure 3). The results from the home range estimation using the 80% KUD method also showed that the dhole in the BNP had a smaller home range size compared to the dhole in India with a home range size of 1560 ha [27], although the difference was not as big as with the MCP's. The home range estimation area based on the LoCoH method was 479.59 ha and 67.37 ha for the home range size (90% LoCoH) and the core area (50% LoCoH), respectively (Figure 4).

The home range encompassed water resources, hunting grounds to the north and on the south side of the home range, and active dens which were located in the center of the home range. During the observations, the presence of dholes in the hunting grounds was mostly during daylight hours or at night with

moonlight. The mean daily distance of radio-collared dhole movements was 1.11 km (± 0.37 SE), with minimum and maximum distances of 0.082 km and 3.7 km. The average speed of dhole movement was 0.79 km/h (± 0.28 SE) with the maximum speed found to be 4 km/h. This information confirms that this species prefers to use the ambush method rather than the chase method to capture their prey.

Table 1. A description of the characteristics of the active den.

	Den I	**Den II**	**Den III**
Occupancy period	12 - 26 August 2014	27 August - 11 September 2014	12 - 26 September 2014
Den characteristics			
Entrance direction	south	south	northwest
Number of entrances	1	1	3
Number of chambers	1	2	3
Height of entrance (cm)	40	50	20-30
Width of entrance (cm)	90	120	20-30
Depth of den (cm)	350	380	450-500
Distance to last den (m)		40	283
Den vicinity characteristics			
Distance to nearest water resource (m)	338.4	382.3	680
Canopy closure (%)	65	70	20
Ground cover (%)	0	5	25
Slope (%)	65	60	30
Surface components (%)			
- Soil	51.25	61.25	68.75
- Rock	30	25.75	22.5
- Leaf litter	12.5	7	6.25
- Decayed wood	6.25	6	2.5
Vertical cover density (%)			
0-30	65.83	73.33	45.83
30-100	91.07	87.50	30.36
100-200	73.75	72.5	15
200-300	62.5	32.5	11.25

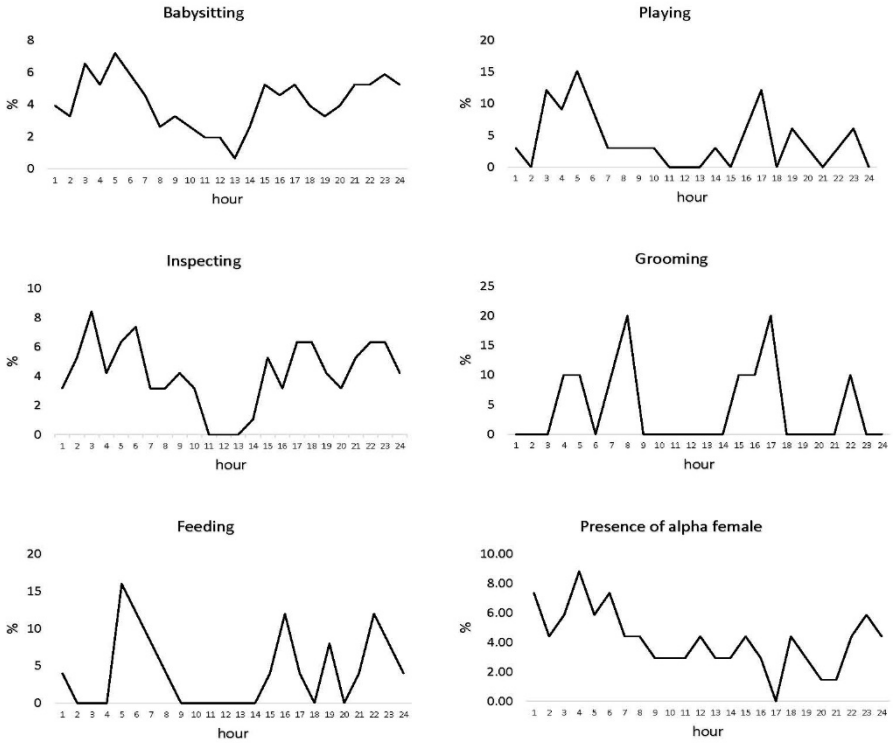

Figure 1. Dhole activity patterns in the den showing frequency of occurrence: babysitting, inspecting, feeding, playing, grooming and presence of the alpha female in the den.

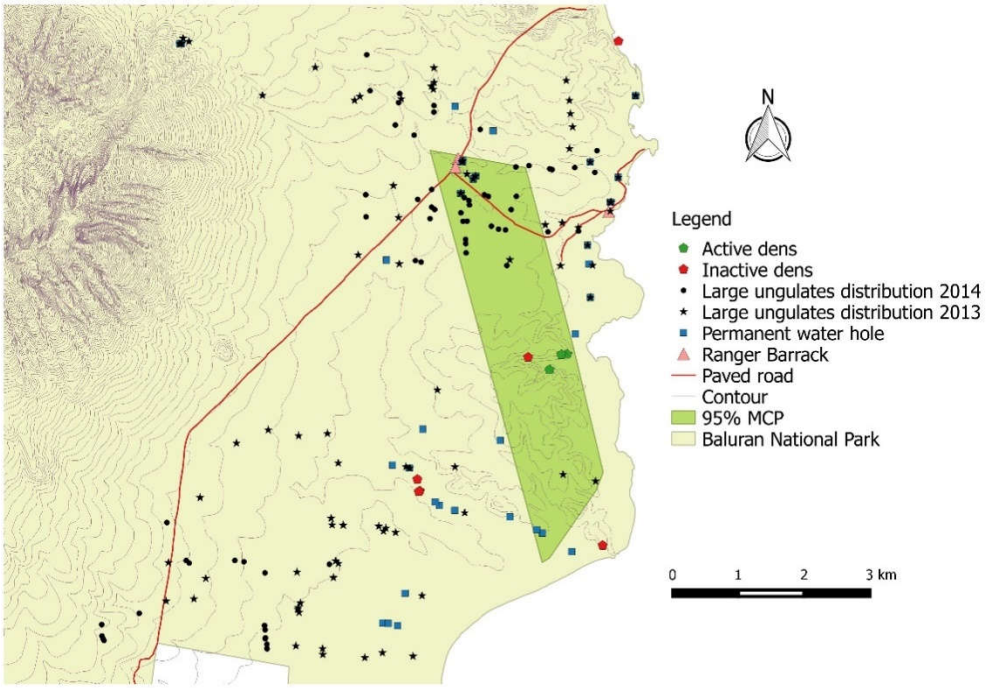

Figure 2. Home range estimate using the 95% Minimum Convex Polygon (MCP) method.

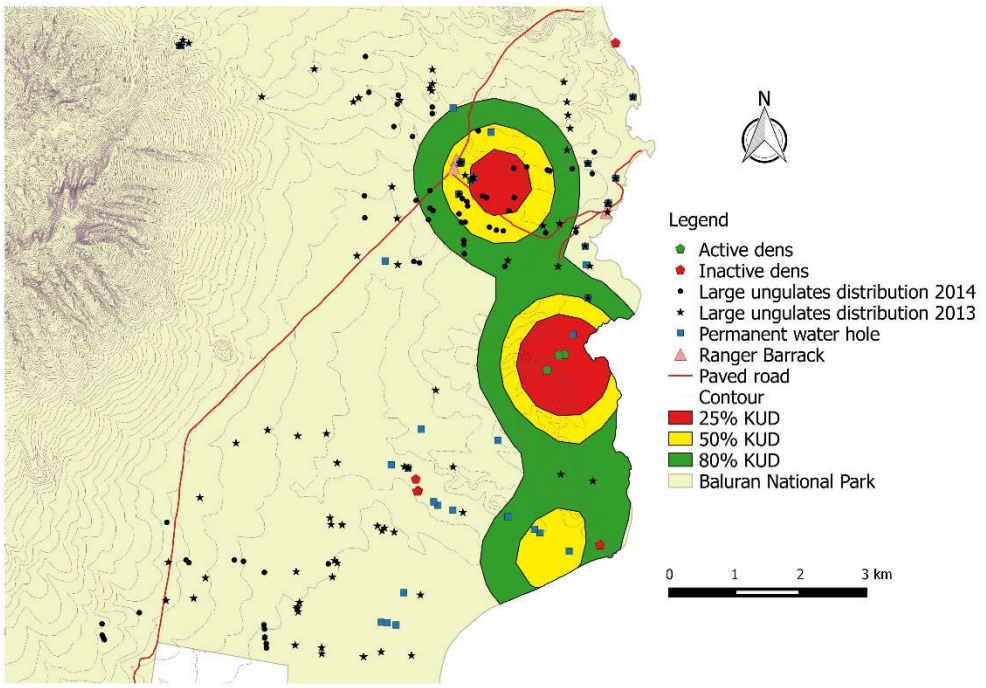

Figure 3. Home range estimate using the Kernel Utilization Distribution (KUD) method: 80% KUD for home range size, 50% KUD for the core area, and 25% for the highest use area.

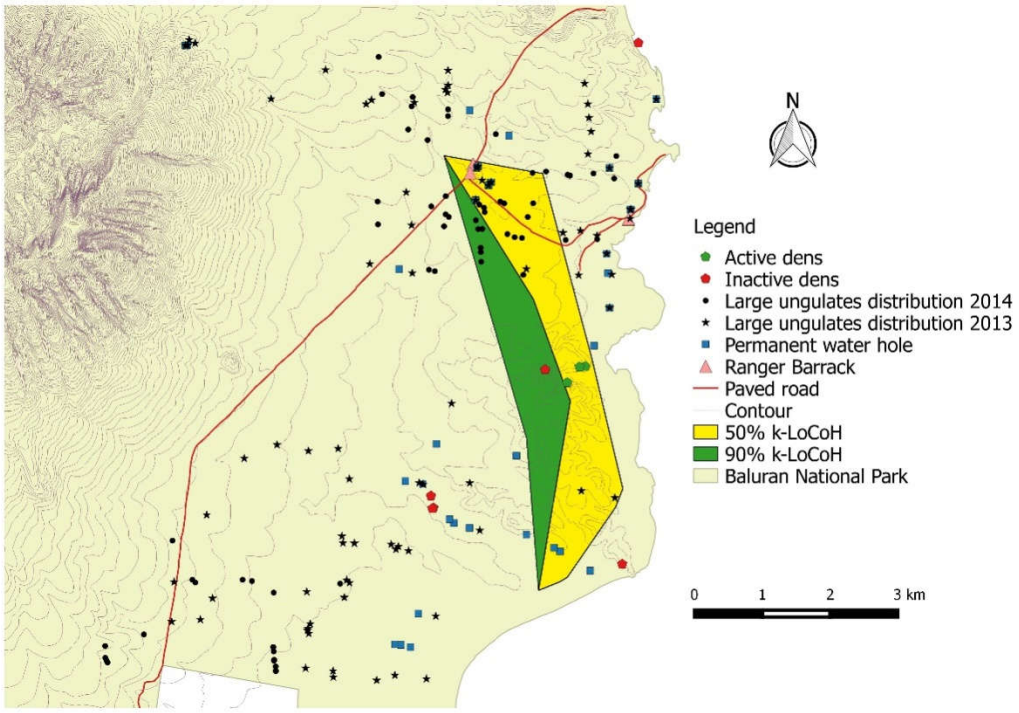

Figure 4. Home range estimate using the fixed k Local Convex Hull (k.LoCoH) method: 95% for home range estimate and 50% for the core area.

DISCUSSION

The results of this study showed that the den structures of dholes in the BNP were similar to the Indian dholes which were constructed under rocks with one or multiple entrances [9]. The surface component was mainly sandy soil, enabling rapid water drainage. It was very likely that the dholes had rebuilt the porcupine's den, as indicated by the porcupine carcass close to the second den. Canids have been commonly known to use the burrows of other animals in the wild [5, 9]. The dens were relatively clean and no bones were found within the dens. It is probable that the dholes did not bring prey carcasses back to the den with them to conceal the presence of an active den site, as also reported in India [9].

The location of the den sites were not distributed randomly across the landscape but selected based on factors such as food availability, shelter from extreme weather conditions or safety from predator disturbance [3, 7]. In this investigation, all of the active den sites were located in the middle of the dholes' home range, enabling access to water resources and prey. The den positions were strategic and provided a convenient place to access resources. Consequently, the dholes were able to maximize their energy efficiency in finding food and maximizing energy delivery to the pups. Good access to resources coupled with optimal den positions in the BNP also minimizes threats. The dens were located on the east side of the hillside, which were characterized by a dense cover and situated on the steep slope in an opposite direction to that in which human activities mostly occur. This indicates that dholes selected den sites that minimized the risk of encountering humans, while disturbance stimuli caused by humans could be comparable to predation risk [36]. The selection of relatively rugged terrain for denning sites as a strategy of predator evasion was also reported for African wild dogs [3].

The dholes in the BNP showed a tendency of crepuscular and diurnal activity patterns as was also reported for dholes in India [9, 37] and Thailand [20, 38]. Most activities in the den intensified at dawn and dusk and became less intensive in the middle of the day. This pattern most likely occurred because most adult dholes spent the daytime hunting [9, 37]. The temporal activity patterns of dholes were primarily driven by prey activity [37], which were mostly large ungulates [39-41]. Because the dholes were also found to provide food during the night, this indicated that they were also likely to hunt at night. However, further study of the dhole's diet would be required to gain evidence of the nocturnal hunting activity. The babysitting and inspecting behaviour were relatively intensive at night as an anti-predator behavioural strategy against nocturnal leopards. Leopards are known as competitors to dholes in the wild [37, 42] and are capable of killing dholes if encountered alone or in pairs [43]. However, until now there has still been no evidence of leopards killing dholes in the BNP.

Male canids are rarely involved in the selection and making of dens [44]. However, in this investigation, we found that male dholes contributed to making dens and rearing pups in the BNP. The male was

observed expanding the porcupine den while guarding the pups. We suspected that the male was altering the den to suit their needs, while guarding the pups. We could not identify whether the males or females mainly contributed to the process of selecting and constructing the den. Malcolm (1985) suggested den selection and den making to be a female prerogative in canids. The den was not only used for looking after the pups, but also the injured adult dholes. The individuals with the role of babysitting, the injured adults, the alpha female and the pups received regurgitated food from the other pack members. This habit facilitates greater efficiency in and the opportunity of food sharing [4].

The movements of denning dholes in the BNP seem to be driven by food and water resources. This evidence can be seen on the home range map (Figures 2, 3, and 4), showing the home range cover including the location of sources of water and prey. A previous study conducted in India reported that the dholes' home range sizes were smaller in the dry season [9, 27, 29], not because of the denning season, but more as a result of water scarcity, confining the pack and prey to areas with perennial water resources [29]. The biggest pack in the BNP – the Bama pack [45] appears to occupy the most prosperous area of the park, which included dens relatively close to water resources and hunting grounds, meaning that energy costs in obtaining food can be minimized, and in return the fitness of the pack members (including the pups) can be maximized. The availability of food and the energetic of nutritive input for the mother and pups can not only alter the group and litter size, but also the mating system [4]. Therefore, ensuring that water resources and prey are available should be a major focus of the BNP management in conserving this species. For future investigations, it is worth taking into account that paddle traps proved to be an effective method for capturing this species compared to other methods (box traps and snare traps) as was also reported for investigations on dingo (*Canis lupus dingo*) in Australia [46]. We therefore recommend using this method for future research. An enhanced collar for the telemetry device is necessary to prevent the collar from breaking as a result of continuous chewing from other pack members, as was also reported for dholes in India [27].

CONCLUSION

This research provides early knowledge on the denning ecology strategy of dholes in the BNP. The dholes used available dens located in an area with high quality habitat, which fulfils their needs for shelter, water, food, and predator evasion. The dholes showed a high den dependence in the denning season, which was reflected by their behaviour of high site fidelity. Therefore, for the conservation and management of this species, securing and protecting those areas, which are potentially used as dens by dholes during the denning season is crucial. To support these research findings, another investigation is necessary to identify the availability of dens. This study was limited to the data from a single pack, therefore further work involving other packs should be conducted to identify variations in denning ecology and movement patterns of this species in the landscape of the BNP, which might contribute to pack-pack interactions. A long-term study on den ecology would provide good estimates of reproductive success of the dhole population in the BNP.

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