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The Influence of Anthropogenic Activities and Availability of Prey on the Distribution of Dholes in a Dry Deciduous Forest of East Java, Indonesia

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ABSTRACT

The dhole (*Cuon alpinus*) is one of the least studied endangered top predators inhabiting the Island of Java. Nowadays, their distribution is known to be fragmented and restricted to a few protected areas in the eastern and western parts of the island. An understanding of the response of this species to various environmental conditions in its natural habitat is critical for its conservation and management. We studied the impact of anthropogenic activities and environmental factors on the dhole's distribution in the Baluran National Park in East Java in Indonesia. The impacts of human activities as well as environmental factors on the presence of dholes were studied on 755 plots, which were distributed systematically across the park and their relationships were analyzed using a binomial generalized linear model. We found that the presence of dholes was negatively associated with anthropogenic activities and positively associated with the presence of prey. This suggests that reducing anthropogenic activities and ensuring the availability of natural prey are crucial factors for maintaining the long term survival of this species in their natural habitat.

Key words: Anthropogenic activity, environmental factor, generalized linear model, habitat, prey, top predator

INTRODUCTION

Predators play a crucial role in maintaining the health of their ecosystems (Estes, Crooks & Holt, 2001) due to the fact that apex-predator species occupy the highest trophic level (Ordiz, Bischof & Swenson, 2013). Their major influence in initiating top-down effects and trophic cascades in various ecosystems have been reported for both, marine (Williams, Estes & Springer, 2004; Heithaus, Wirsing & Dill, 2012; Heupel *et al*., 2014) and terrestrial ecosystems (Miller *et al*., 2001; Ripple & Beschta, 2004; Beschta & Ripple, 2009; Ritchie *et al*., 2012; Ordiz *et al*., 2013a). One hypothesis assumes that the loss of large, top predators from several terrestrial systems may lead to mesopredator release, influencing ecological communities across the ecosystem (Estes *et al*., 2001; Prugh *et al*., 2009). The reliance of large carnivores on large spatial and temporal scales, may be the key to bridging the gap between coarse and fine scale conservation strategies (Ray, 2005). Therefore, efforts to conserve top predators are crucial in shaping biodiversity in many systems.

Whilst predator conservation is an emerging issue in the conservation of biodiversity, it still has numerous obstacles to overcome, particularly in developing countries such as Indonesia. Difficulties arise due to predator characteristics for example which are cryptic and hard to understand, compounded by the factor that their food resources often overlap with human interests (Redford, 2005). Predators are sometimes considered as competitors for humans in hunting and are often treated as pests when they kill livestock (Ordiz *et al*., 2013a). Hence, the conservation of large carnivores remains controversial, forcing managers to compromise (Ordiz *et al*., 2013a) and select options that not only accommodate the requirements of large carnivores but also take into account human interests. Sufficient reliable scientific information about the ecology of the managed species thus becomes essential to make the appropriate management and planning decisions. It is imperative to be able to understand how a species responds under various environmental conditions across its range if one has successfully to restore, conserve and manage that species (Morrison, Marcot & Mannan, 2006). Nevertheless, there are still a lot of endangered predators, such as the dhole (*Cuon alpinus*) that according to Acharya *et al*. (2010) and Khatiwada *et al*. (2011) is the least studied carnivore in the world, which still lacking information about their ecology as the basis for their management and conservation.

The dhole inhabits Java in Indonesia, which is one of the most populated islands in the world. In the

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past, this species was widely distributed on Java (Hoogerwerf, 1970). Nowadays, however, its distribution is highly fragmented with the dhole struggling to survive in a handful of protected areas in the eastern and western parts of the island (Durbin *et al*., 2004). The dhole's predation on endangered banteng (*Bos javanicus*) (Pudyatmoko & Djuwantoko, 2006; Pudyatmoko, Djuwantoko & Sabarno, 2007) has raised issues about its conservation, due to an endangered predator killing endangered prey (Macdonald & Sillero-Zubiri, 2004), meaning that management efforts to reduce dhole pack size seem necessary to protect the banteng population even if this is not an easy choice (Pudyatmoko *et al*., 2007). Furthermore, the fact that dholes prey on livestock means that they are often regarded as pests throughout most of their natural range (Cohen *et al*., 1978; Fox, 1984; Wangchuk, 2004; Wang & Macdonald, 2006; Johnsingh, Yonten & Wangchuck, 2007; Wang & Macdonald, 2009; Khatiwada *et al*., 2011; Thinley *et al*., 2011; Selvan *et al*., 2013). This derogative image of the dhole has meant that this species has received less attention in conservation, resulting in a lack of knowledge about their role in Asia's predator guild beyond site-specific studies (Hayward, Lyngdoh & Habib, 2014).

In spite of its importance, scientific information about dhole ecology is very rare. Although studies on dholes have started to increase, these have focused mainly on diet profiles (Karanth & Sunquist, 1995; Grassman *et al*., 2005; Andheria, Karanth & Kumar, 2007; Thinley *et al*., 2011; Hayward *et al*., 2014) and behaviour (Cohen *et al*., 1978; Johnsingh, 1982; Venkataraman *et al*., 1995; Karanth & Sunquist, 2000; Venkataraman & Johnsingh, 2004; Kawanishi & Sunquist, 2008; Borah *et al*., 2009; Wang & Macdonald, 2009; Selvan *et al*., 2013). Studies on interactions between dholes and their environment are still limited (Steinmetz, Seuaturien & Chutipong, 2013; Srivathsa *et al*., 2014). Moreover, all previous studies on dholes were conducted on mainland Asia, which only accounts for a relatively small proportion of the dhole's extensive range in the wild. We carried out the first study on the impacts of anthropogenic activities and environmental factors on dhole distribution in the Baluran National Park (BNP) in Indonesia. This park has been exposed to high anthropogenic pressure for natural resources. According to BNP's policy on the utilization of the conservation area, local people are allowed to access the natural resources within the park to support their subsistence livelihoods (Winnasis *et al*., 2011). However, the number of people living in or entering the park are a serious problem, not least because of the fact that they increase the risk of accidental and deliberate fires being started (Whitten, Soeriaatmadja & Affif, 1996). In 2013, at least 4 packs of dhole were identified in the park (Nurvianto *et al*., 2015, in press). The negative response of carnivores towards anthropogenic activities has been reported for brown bears (*Ursus arctos*) (Ordiz *et al*., 2011; Ordiz *et al*., 2013b), spotted hyenas (*Crocuta crocuta*) (Boydston *et al*., 2003; Pangle & Holekamp, 2010), Amur tigers (*Panthera tigris altaica*) (Kerley *et al*., 2002), and wolves (*Canis lupus*) (Hebblewhite *et al*., 2005). The negative influence of anthropogenic activities on dhole distribution has also been reported in India at the landscape level as well as at the reserve scale (Srivathsa *et al*., 2014). Nevertheless, the evidence of the dhole's response to anthropogenic activities and the extent of environmental factors beyond site-specific studies are needed to support the management and conservation of dholes at the local scale, which might be associated with different habitat types and environmental conditions. This study generates crucial information concerning the response of the dhole's population to various habitat characteristics beyond mainland Asia, especially in Java. We hypothesized that: 1) anthropogenic activities would have a negative impact on the dhole's presence, and 2) the presence of dholes at a certain location did not occur randomly, but followed particular habitat features (e.g. the presence of prey, physical conditions and the structure of vegetation) for that particular location. The dhole's response to anthropogenic activities and habitat factors are discussed thoroughly in this paper.

MATERIALS AND METHODS

We conducted our research in the Baluran National Park (BNP) on the island ofJava in Indonesia. This park is located in the northeast of Java with the bearings 70029'10'' to 70055'55'' S and 113029'10''-113039'10'' E and covers ca. 25,000 ha (Figure 1). The park is characterized by a monsoon climate with a long dry season from April to November with most precipitation from December to February (Pudyatmoko & Djuwantoko, 2006). The annual precipitation is less than 1500 mm, which makes this park the driest national park in Java (Winnasis *et al*., 2011) due to the fact that precipitation is close to zero during the driest months (August-November) (Pudyatmoko *et al*., 2007). Elevations of the BNP landscape range from 0 in coastal areas in the northern and eastern parts to 1,268 above sea level at the peak of Mount Baluran in the middle of the park (Winnasis *et al*., 2011). The habitat types found in this park are costal forest, mangrove forest, temporary wetland, savanna, shrubland, primary forest, secondary forest, *Acacia nilotica* 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 (*Sus scrofa*), with the only large carnivore other than the dhole being the leopard (*Panthera pardus*) (Pudyatmoko *et al*., 2007). The park has experienced tremendous anthropogenic pressure from local people in the form of harvesting, herding, illegal logging, and poaching taking place throughout the year. These activities tend to increase during the dry season, particularly at locations that can be easily accessed by people (Winnasis *et al*., 2011).

The field survey was conducted in September-November 2013 during the dry season in the BNP. The study area consists of 755 plots which were distributed based on systematic random design (Morrison *et al*., 2001) with the distance between centers of plots set to 500 m (Figure 1). The location of each plot was determined before the survey using a digital topographic map of the BNP and ArcGIS 10.1 software (Environmental Systems Research Institute/ESRI) for this purpose. The presence and absence of dholes and signs of prey

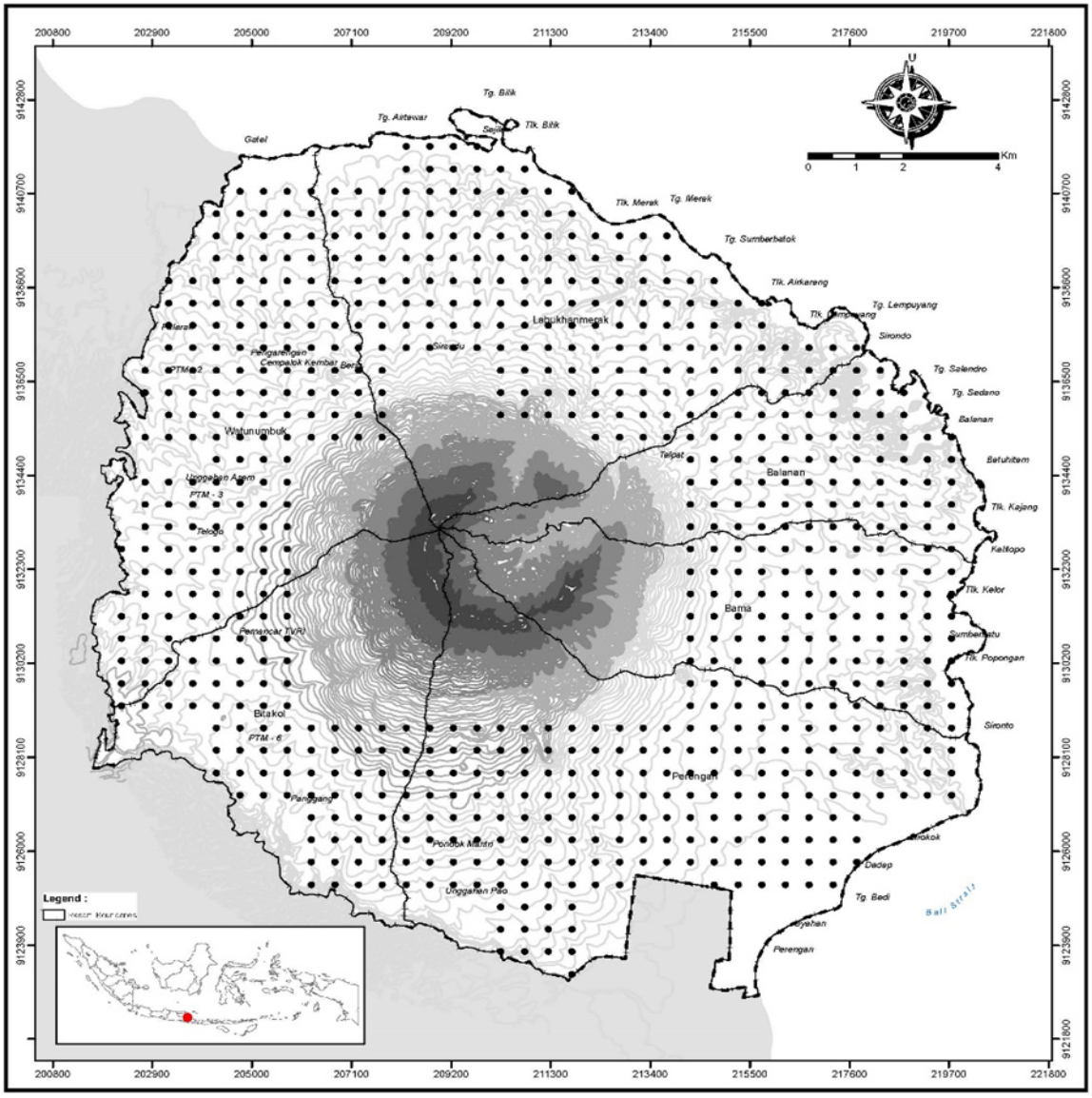

Figure 1. Map of the study area in the Baluran National Park. Dots represent the distribution of study plots in the whole area.

(i.e. direct observations, faeces, tracks, and prey carcasses), as well as human activities within a radius of 150 m from the center of the plots were recorded. We only recorded signs of large ungulates i.e. banteng, buffalo, wild boar or Javan deer, because they are known to be the most important prey for dholes in their natural range (Borah *et al*., 2009; Wang & Macdonald, 2009; Thinley *et al*., 2011). Plots with signs of presence of dholes, prey or human activities were recorded as 1, and otherwise recorded as 0. To avoid biases arising from misidentification, we only recorded those signs that were fresh and could be correctly identified. The fieldwork was conducted by two teams with each of them consisting of three experienced surveyors in recognizing mammal signs. The variables of human activities, i.e. illegal logging, herding, harvesting (i.e. fruits, grass, wild yam, tubers, honey, insects larvae, seeds (gebang palm (*Corypha utan*) and *Acacia nilotica*), collecting fuel wood), poaching, and tourism were measured by identifying signs of those activities within the plots. In order to investigate the impact of environmental factors, a 0.04 ha circular plot was established at the center of each 150 m radius plot. The protocol sampling procedure (Noon, 1981) was employed to identify those habitat variables that influence the dholes' presence. This sampling is based on the multivariate approach to habitat selection. Based on that approach, we measured 22 habitat variables in each plot (Table 1). For macrohabitat analysis, habitat type, distance to the nearest water resource and settlement were measured using ArcGIS 10.1. In total, this research covered 7 habitat types, i.e. *A. nilotica* stands (AN), managed forest (MF), mangrove forest (MgF), primary forest (PF), savanna (SV), secondary forest (SF), and shrubland (SH).

We analyzed the effect of human activities and habitat factors on dhole distribution separately using a generalized linear model (GLM) with a binomial error distribution (McCullagh & Nelder, 1989). GLM is considered to be a technique for modelling species distribution, which focuses on the general trends of species presence/ absence responses. This technique is expected to provide reasonable models for species responding to environmental gradients as predicted by simple response curves (Segurado & Araujo, 2004). We tested whether

Table 1. List of environmental variables for predicting the probability of the presence of dholes in Baluran National Park.

No.	Variable	No.	Variable
Macrohabitat			
1	Habitat type		
2	Distance from water (km)		
3	Distance from settlement (km)		
Microhabitat			
1	Canopy closure (%)		*Tree density* (individual/ ha):
2	Ground cover (%)	13	S (3 ≤ dbh < 8 cm)
	Vertical foliage density (%):	14	A (8 ≤ dbh < 15 cm)
3	0-30 cm,	15	B (15 ≤ dbh < 23 cm)
4	30-100 cm,	16	C (23 ≤ dbh < 38 cm)
5	100-200 cm,	17	D (38 ≤ dbh < 53 cm)
6	200-300 cm	18	E (53 ≤ dbh < 69 cm)
	Surface component (%):	19	F (69 ≤ dbh < 84 cm)
7	soil,	20	G (84 ≤ dbh < 102 cm),
8	rock,	21	H (102 ≤ dbh))
9	leaf litter,	22	Sapling (dbh< 3 cm, high > 40 cm)
10	decayed wood coverage		
11	Woody stem cover (hight ≤ 40 cm)		
12	herbaceous stem cover (hight ≤ 40 cm)		

human activities have a significant effect on dhole distribution at the microhabitat as well as the macrohabitat level. For the microhabitat level model, the presence or absence of all human activity variables (i.e. illegal logging, herding, harvesting, poaching or tourism) were treated as explanatory or independent variables while dhole presence (present/absent) was considered to be a dependent variable. At the macrohabitat level on the other hand, the habitat type variable (categorical) was incorporated into the model as an exploratory variable. We attempted to identify whether human activities in the different habitat types influenced the probability of the dhole's presence in the BNP through the model. Similarly, with the aforementioned model, for the microhabitat model, the prey variable (present/absent) and 22 habitat variables were treated as independent variables and the dhole presence (present/absent) was treated as a dependent variable. For the macrohabitat model, several independent variables were added to microhabitat model (i.e. habitat types, distance to each plot, distance to the nearest water resource, and distance to the nearest settlement). This model was developed to identify which habitat variables are important determinants of dhole distribution in the BNP.

All statistical analyses were performed using R 3.1.2 software (R Development Core Team 2014).We used model selection tests based on Akaike information criteria (AIC) (Burnham & Anderson, 2002) embedded in the GLM function. Information-theoretical approaches, such as AIC, provide a framework that allows multiple model comparisons to be made and the most parsimonious of these models to be identified (Rhodes *et al*., 2009). The model with the lowest AIC was considered to be the most parsimonious model (Burnham & Anderson, 2002). The best minimal adequate model was achieved by backward elimination of non-significant effects of explanatory variables in the model, with each variable only being retained in the model if it caused a significant increase in deviance when it was removed from the current model (Crawley, 2007). Due to missing data, 4 plots were eliminated before the analysis.

RESULTS

In total, signs of dholes and their prey were found on 54 and 74 plots, respectively. Presence signs of dholes were found in all habitat types and mostly in SV (n = 18) and SF (n = 18), while presence signs of prey were found in all habitat types except for PF (n = 0) and mostly in SH (n = 27), AN (n = 17), and SV (n = 8) (Figure 2).

We found signs of anthropogenic activities in 331 out of 755 plots, and mostly in SF (n = 96) and SV (n = 89) (Figure 3). Harvesting of non-timber forest products was the most dominant activity (n = 219) and could be found in all habitat types, although it mostly occurred in SF (n = 69), SH (n = 52) and MF (n = 50). Illegal logging (n = 110) was the second most common activity found in all habitat types except for AN (n = 0) and MgF (n = 0), and mostly occurring in MF (n = 31) and SF (n = 31). Herding (n = 108) was the third most common activity found in all habitat types except for PF (n = 0), and intensively occurring in SV (n = 85). Poaching activities (n = 25) were found in all habitat types except for MF (n = 0) and PF (n = 0), and mostly occurred in SF (n = 8), SH (n = 8), and MgF (n = 6). During the survey, signs of poaching (traps and hunting huts) were generally found near water sources. Tourism (n = 3) was low compared to other anthropogenic activities in the BNP, and only

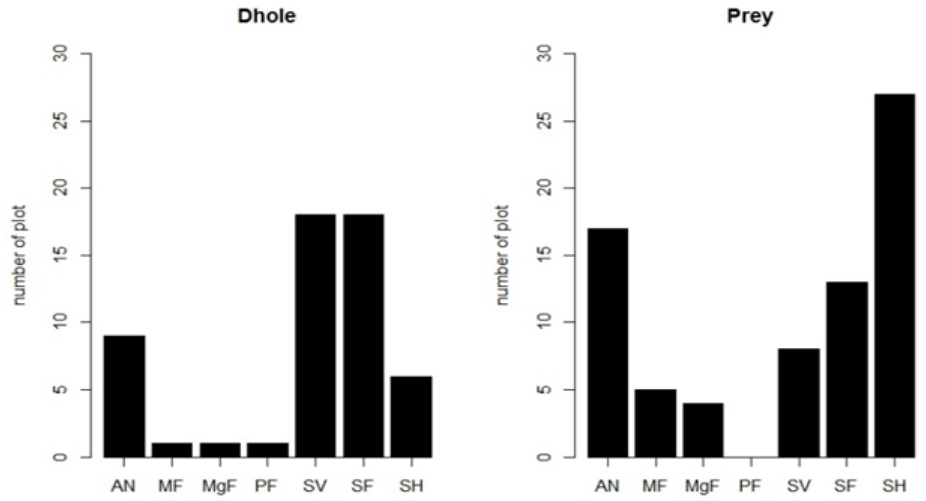

Figure 2. The plot numbers of presence signs of dholes and prey in different habitat types in the Baluran National Park: *Acacia nilotica* stand (AN), managed forest (MF), mangrove forest (MgF), primary forest (PF), savanna (SV), secondary forest (SF), and shrubland (SH).

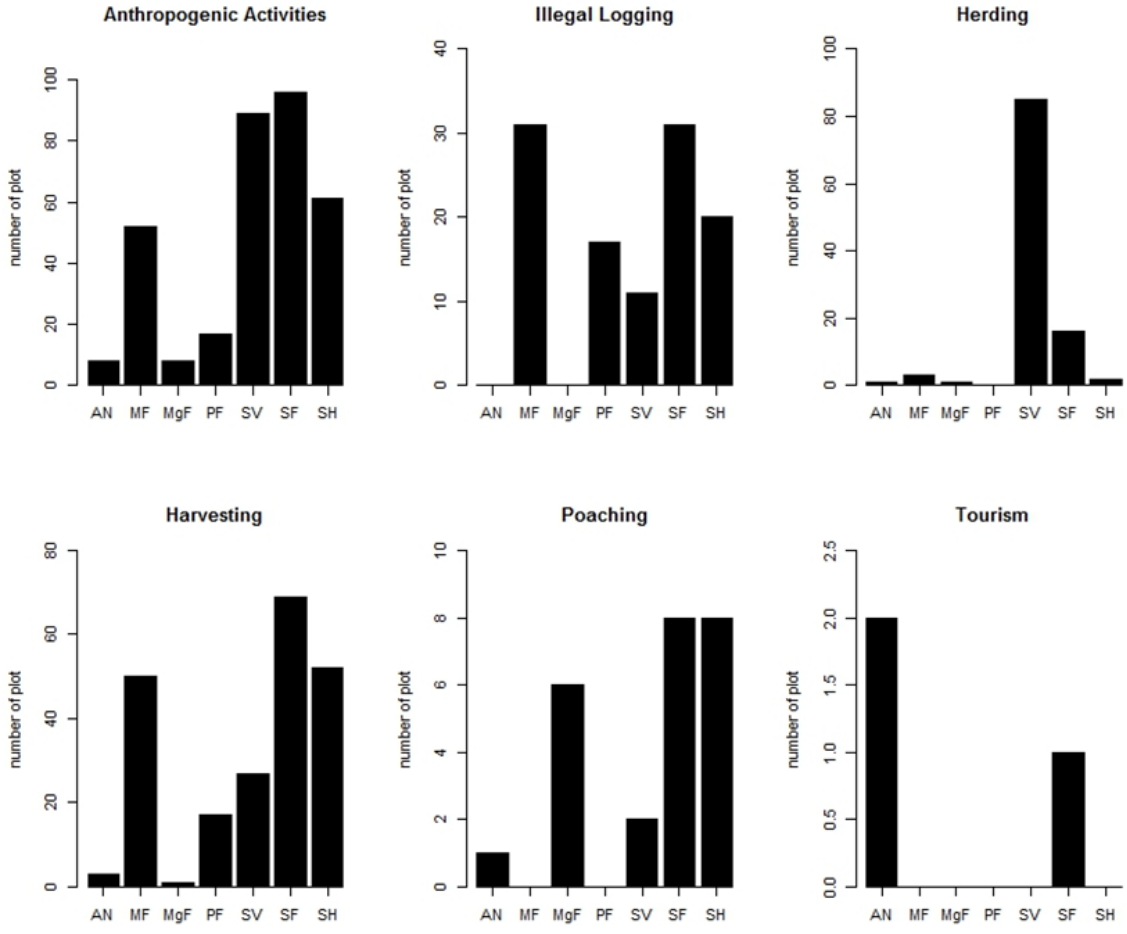

Figure 3. The plot numbers of anthropogenic activities in different habitat types in the Baluran National Park: *Acacia nilotica* stand (AN), managed forest (MF), mangrove forest (MgF), primary forest (PF), savanna (SV), secondary forest (SF), and shrubland (SH).

occurred in two habitat types AN (n = 2) and SF (n = 1).

We found that overall anthropogenic activities had a significant effect on the presence of dholes in the BNP. The results of the analysis showed that harvesting activities have a significant negative effect on the presence of dholes at the microhabitat level (-1.7184 ± 0.5260, P < 0.01) (Table 2), with dholes tending to avoid locations with harvesting activities. Similar results were also found at the macrohabitat level, where herding activities (-1.1454 ± 0.5309, P < 0.05) and harvesting activities (-1.3583 ± 0.5440, P < 0.05) have a significant negative impact on the presence of dholes, especially in the habitat types AN and MF (Table 1). The effect of herding and harvesting activities on the probability of the presence of dholes in every habitat type can be seen in Figure 4.

The presence of dholes is significantly associated with environmental factors both at the macrohabitat and the microhabitat level. The results of the analysis at the microhabitat level indicated that the presence of dholes was significantly associated by the presence of prey, soil surface (%), foliage density 0 -30 cm (%) and foliage density 30 – 100 cm (%) (see Table 2). The presence of prey (1.064094 ± 0.370540, P < 0.01), soil surface (0.012763 ± 0.005198, P < 0.05), and foliage density 0 - 30 cm (0.052931 ± 0.023267, P < 0.05) all had positive effects on the model whereas the variable foliage density 30 – 100 cm (-0.057522 ± 0.013936, P < 0.001) had a negative effect. Although the soil surface and foliage density were significant, their effect on the model were weak. Only the presence of prey had a strong effect on the model.

Table 2. The best minimal adequate model to predict the presence of dholes in Baluran National Park. The significance of each explanatory variable was tested using the Z test. The significance value of each variable was shown as: *** P < 0.001, ** P < 0.01, * P < 0.05.

Variables	Estimate	SE	Z	P	AIC
Anthropogenic factors					
Microhabitat (Dhole~Harvesting, Res.Dev.=371.56, df=749)					
Intercept	-2.2659	0.1486	-15.251	< 2e-16 ***	375.56
Harvesting	-1.7184	0.526	-3.267	0.00109 **	
Macrohabitat (Dhole~HabitatType+Herding+Harvesting, Res.Dev=356.08, df=742)					
Intercept	-1.8668	0.3579	-5.216	1.83e-07 ***	374.08
Managed Forest (MF)	-2.2105	1.0742	-2.058	0.0396 *	
Mangrove Forest (MgF)	-1.1085	1.0854	-1.021	0.3071	
Primary Forest (PF)	-0.8135	1.0982	-0.741	0.4589	
Savanna (SV)	0.358	0.4619	0.775	0.4384	
Secondary Forest (SF)	-0.39	0.4374	-0.892	0.3726	
Shrub (SH)	-0.6827	0.5603	-1.218	0.2231	
Herding	-1.1454	0.5309	-2.158	0.0310 *	
Harvesting	-1.3583	0.544	-2.497	0.0125 *	
Environmental factors					
Microhabitat (Dhole~Prey+SoilSurface+Foliage Density 0-30 cm+Foliage Density 30-100 cm, Res.Dev=344.32, df=746)					
Intercept	-2.77361	0.383278	-7.237	4.60e-13 ***	354.32
Prey presence	1.064094	0.37054	2.872	0.00408 **	
Soil surface (%)	0.012763	0.005198	2.455	0.01407 *	
Foliage density 0-30 cm (%)	0.052931	0.023267	2.275	0.02291 *	
Foliage density 30-100 cm (%)	-0.05752	0.013936	-4.128	3.67e-05 ***	
Macrohabitat (Dhole~HabitatType+Prey+SoilSurface+Foliage Density 300-100 cm, Res.Dev=337.67, df=741)					
Intercept	-2.07849	0.45381	-4.58	4.65e-06 ***	357.67
Managed Forest (MF)	-2.3734	1.08385	-2.19	0.028539 *	
Mangrove Forest (MgF)	-0.809	1.11065	-0.728	0.466367	
Primary Forest (PF)	-0.1247	1.12116	-0.111	0.911436	
Savanna (SV)	-0.0647	0.47073	-0.137	0.890677	
Secondary Forest (SF)	-0.04521	0.47269	-0.096	0.923795	
Shrub (SH)	-0.36253	0.59196	-0.612	0.540255	
Prey presence	1.01721	0.39966	2.545	0.010923 *	
Soil surface (%)	0.01141	0.00525	2.173	0.029780 *	
Foliage density 30-100 cm (%)	-0.03505	0.01052	-3.331	0.000865 ***	

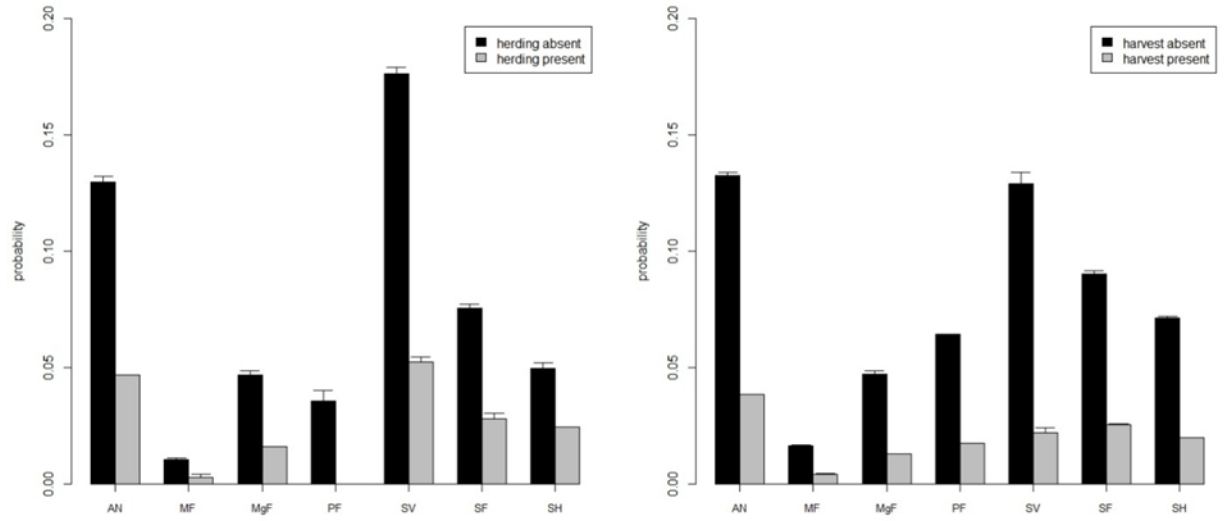

Figure 4. The mean probability and standard error of dhole presence associated with herding activities and harvesting activities in different habitat types in the Baluran National Park: *Acacia nilotica* stand (AN), managed forest (MF), mangrove forest (MgF), primary forest (PF), savanna (SV), secondary forest (SF), and shrubland (SH).

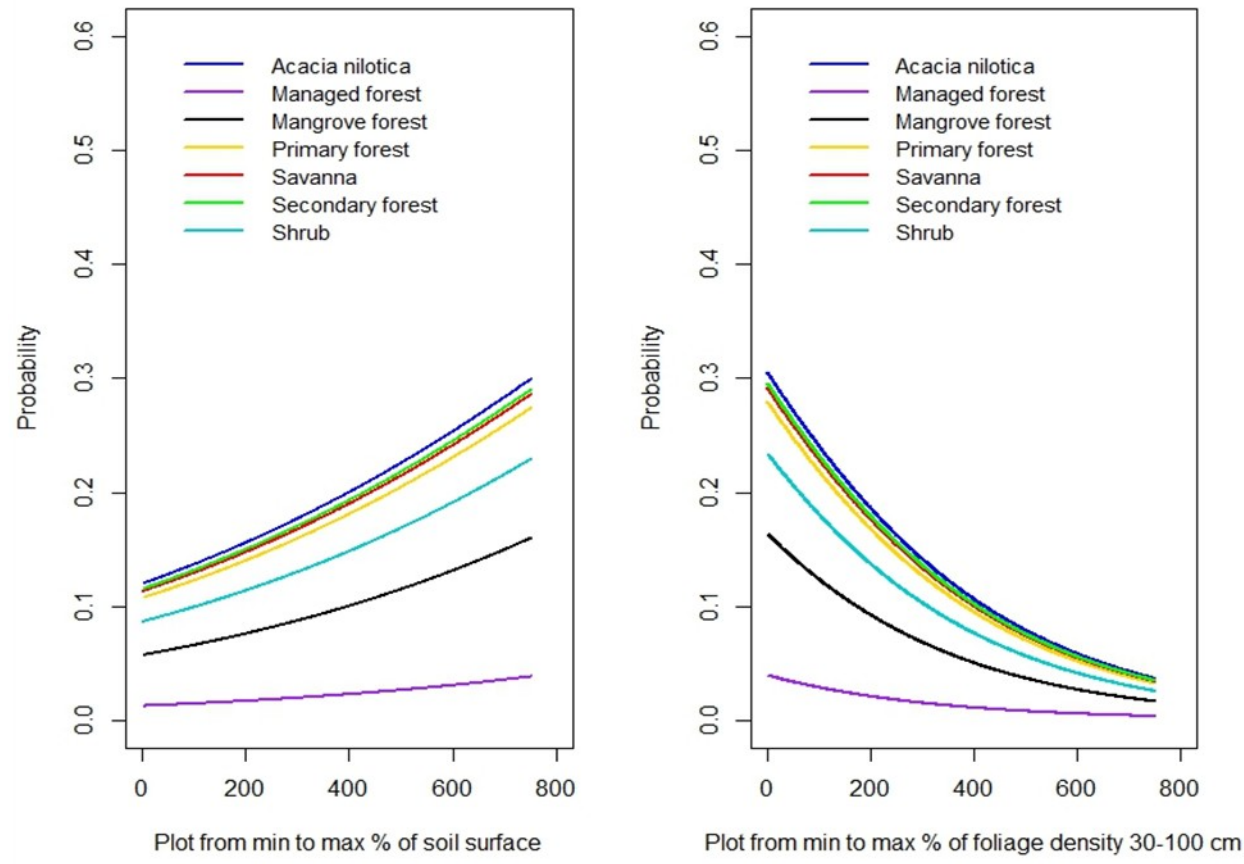

Figure 5. The probability of dhole presence in relation to the environmental gradient factors i.e. soil surface (%) and foliage density 30-100 cm in different habitat types in the Baluran National Park.

For the macrohabitat model, the presence of dholes was strongly associated with habitat type, the presence of prey, soil surface and foliage density 30 -100 cm. The presence of prey (1.01721 ± 0.39966, $P < 0.05$) and soil surface (0.01141 ± 0.00525, $P < 0.05$) had positive effects on the model, while foliage density 30 – 100 cm (-0.03505 ± 0.01052, $P < 0.0001$) had a negative effect. The model simulation showed that habitat type which has the highest probability of effecting the presence of dholes was AN, followed by SF, SV, PF, SH, MgF and MF, respectively (Figure 5).

DISCUSSION

The results of this study have proven that both hypotheses are accepted: anthropogenic activities had a negative impact on the presence of dholes and the presence of dholes does not occur randomly, but follows particular habitat features at each locality. Based on the best minimal adequate model, harvesting activities of non-timber forest product were negatively associated with the presence of dholes in the BNP. During the field research, the harvesting of non-timber forest products i.e. for tamarind fruit (*Tamarindus indica*), insect larvae (for bird feed), grasses (for livestock), fuel wood, honey, seeds (gebang palm and *A. nilotica*), and tubers of wild yam (*Dioscorea hispida*) occurred in the BNP. As part of the principle of utilization within the conservation area, the BNP policy allows people from local villages to access the resources within the park to support their subsistence livelihoods (Winnasis *et al*., 2011). However, due to a weak regulation and control system, harvesting activities become uncontrolled and occur extensively in this park. Uncontrolled harvesting activities without any spatial and temporal restrictions will negatively affect the health and balance of the ecosystem, which is reflected by the disappearance of predators (Ordiz *et al*., 2013a). Dholes tend to be avoiding those places where non-timber forest products are harvested to avoid conflicts. Similar cases have been observed for carnivores in the past, such as with brown bears (Ordiz *et al*., 2011; Ordiz *et al*., 2013b), spotted hyenas (Boydston *et al*., 2003; Pangle & Holekamp, 2010), Amur tigers (Kerley *et al*., 2002), and wolves (Hebblewhite *et al*., 2005), which showed negative responses to anthropogenic activities. In these cases, the carnivores avoided the humans because they considered humans as predators (Frid & Dill, 2002).

Besides harvesting activity, herding activity was also negatively associated with the presence of dholes at the macrohabitat level. The availability of extensive savanna in the BNP has attracted people to herd their livestock inside the park, especially in the northern and western parts of the park that are directly adjacent to local villages. This situation increases the probability of human-wildlife conflict within the park. The occurrence of herding activities inside the reserves has been reported to have a positive association with the loss of livestock due to predation from carnivores (Wang & Macdonald, 2006; Johnsingh *et al*., 2007), even though the number of losses was strongly dependent on the guarding effort (Karanth *et al*., 2013). As reported by local people, several cases of livestock predation by dholes have occurred in the BNP. Intensive guarding effort was likely to be a factor that reduced the occurrence of livestock predation in the BNP. Nevertheless, the occurrence of livestock predation by dholes should be an early warning for the manager as a sign that the availability of natural prey at the location of the herding activity, has been decreased. The negative influence of livestock presence on dhole and prey distribution at the landscape scale as well as habitat use at the reserve scale has been reported in India (Srivathsa *et al*., 2014).

The disturbance stimuli caused by humans could be comparable to predation risk (Frid & Dill, 2002). Dholes might perceive human disturbance in the BNP as a predation risk even though it might not pose a lethal threat. When dholes start to avoid disturbed habitats, it is often an early sign of their disappearance. Frid and Dill (2002) suggested that disturbance stimuli occurring intensely over a long-term period will cause habitat shift when alternative habitats are available. Otherwise, when alternative habitats are not available, habitat shift will not occur, and as a consequence, their activity budget (e.g. feeding, parental care or mating) will be disrupted. Ensuring that alternative habitat is available at the landscape level and reducing human disturbance in dhole habitat are crucial to support the long term survival of this species. Therefore, further studies to identify the potential habitat of dholes at the landscape level as well as the patterns of human disturbance throughout the year are necessary to implement effective conservation and management actions for this species in the middle of a human -dominated landscape.

The presence of dholes was positively associated with the presence of prey in the BNP. This pattern can be seen from a high frequency of the presence of dholes in those land use types that also reflect a high frequency of the presence of prey (Figure 2) as well as the significant effect of the presence of prey in the best minimal adequate model (Table 2). This result confirmed other studies which have reported that dholes usually use habitat that provides high prey density (Fox, 1984; Venkataraman, Arumugam & Sukumar, 1995; Venkataraman & Johnsingh, 2004; Grassman *et al*., 2005).Therefore, ensuring the availability of natural prey populations, especially large ungulates, is a major factor that must be considered in the management and conservation of dholes in its natural habitat, especially in the BNP.

Other environmental factors which are significantly associated with the presence of dholes were the percentage of soil surface and the vertical foliage density 0 – 30 cm and 30 – 100 cm. The presence of dholes was positively associated with the percentage of soil surface, because dholes were normally detected along wildlife trails and in the proximity of water resources that were mostly not covered by plants. Furthermore, dholes also tend to defecate along the edge of wildlife trails. Vertical foliage density 0 – 30 cm was positively associated with the presence of dholes. The value of this variable describes the vertical ground cover density, which is strongly associated with ungulate herbivory in the tropics (Khan, 1994; Bagchi, Goyal & Sankar, 2003). It would appear that the dholes followed the presence of prey. The

opposite pattern occurred for vertical foliage density 30 – 100 cm which was negatively associated with the presence of dholes. The locations with a high value for this variable have a low probability of dhole presence because those locations with dense vegetation (30-100 cm high) would be difficult to access for the dholes. Although these three environmental variables were significant, their effect in the best minimal adequate model were weak. The management of the BNP should focus more on the presence of prey variable, which has a strong effect on the presence of dholes as also reported in India (Venkataraman *et al*., 1995; Karanth & Sunquist, 2000; Venkataraman & Johnsingh, 2004; Andheria *et al*., 2007; Srivathsa *et al*., 2014), Laos (Kamler *et al*., 2012) and Thailand (Grassman *et al*., 2005).

CONCLUSION

We conducted the first systematic study on the relationship between dholes and their habitat outside of mainland Asia. The negative effects of anthropogenic activities as well as the importance of the presence of prey on the presence of dholes have been demonstrated in this research. In the next step, the management of the BNP should determine immediate management actions to reduce the impact of anthropogenic activities in this park, by defining an appropriate regulation system as well as law enforcement. We recommend that anthropogenic activities should be monitored throughout the year in the BNP to identify the pattern as well as quantify the level of disturbance on dholes and their prey. This study was limited to a single season which only covered a small portion of the complex problem in dhole conservation in the BNP. Further studies should be extended in time and space to capture the variation of anthropogenic activities and environmental factors on dholes over the years. Based on the results of this research, we recommend that efforts to reduce anthropogenic activities and to ensure the availability of natural prey are implemented as soon as possible to ensure the survival of this species in its natural range, particularly in Java.

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