TAPROBANICA, ISSN 1800–427X. March, 2016. Vol. 08, No. 01: pp. 10–20.

www.taprobanica.org

FEEDING HABITS OF PACK LIVING DHOLE (*Cuon alpinus*) IN A DRY DECIDUOUS FOREST OF EAST JAVA, INDONESIA

Section Editor: Colin Groves *Submitted*: 3 November 2015, *Accepted*: 3 March 2016

Sandy Nurvianto[1,2,4], Rury Eprilurahman[3], Muhammad Ali Imron[2] and Sven Herzog[1]

[1] Wildlife Ecology and Management, Dresden University of Technology, Pienner Str. 8, 01737 Tharandt, Germany
[2] Wildlife Ecology and Management Laboratory, Faculty of Forestry, Universitas Gadjah Mada, Indonesia, Jl. Agro No. 1 Bulaksumur, Yogyakarta 55281, Indonesia
[3] Laboratory of Animal Systematics Faculty of Biology, Universitas Gadjah Mada, Jl. Teknika Selatan, Sekip Utara 55281, Indonesia
[4] E-mail: sandy_nurvi@yahoo.com

Abstract
We conducted a study on the feeding habits of dholes in the Baluran National Park, Indonesia. Scat analysis was employed to identify the prey consumed. In total, 54 scats were collected across the park during the dry season of 2013 and analyzed to identify the prey of this species; at least 20 prey species were identified. Ungulates are the most important prey, estimated to contribute more than 95 % of the biomass consumed by dholes in BNP. Efforts to ensure availability of ungulates and to secure habitat will be the key to the dhole's conservation in Java.

***Key words*:** Baluran National Park, conservation, food, predator, prey, scat analysis, ungulates.

Introduction

As top predators, carnivores play a major role in shaping prey communities in the ecosystem (Karanth & Sunquist, 1995; Andheria *et al.*, 2007; Ramesh *et al.*, 2012), hence their effective conservation will enhance the survival prospects of other species (Andheria *et al.*, 2007). The life history strategies of animals depend predominantly upon food, spacing pattern, habitat selection, distribution, social structure and movement pattern (Selvan *et al.*, 2013b), among which food is the most essential resource for carnivores, given that the evolutionary fitness of any predator depends on the quality and quantity of its diet (Johnsingh, 1992). Information on food habits is therefore vital to understand the natural history and ecology of carnivores (Miquelle *et al.*, 1996; Borah *et al.*, 2009; Selvan *et al.*, 2013a, b), and is central to the ecological niche they occupy, plays an important role in explaining their social organisation, behavior, and factors affecting population density, and may also have important implications in the life histories of their prey (Mills, 1992). Carnivore feeding habits reflect both potential prey availability as well as the suite of morphological, behavioral and physiological adaptations that allow the individual to capture and consume prey (Wang & Macdonald, 2009). In addition, resource use by predators and their relationship with prey are important in understanding the mechanisms that influence vertebrate community structure (Ramesh *et al*., 2012), a vital consideration when managers have to make a decisions about the population sizes and species composition of the vertebrate community that will result in the most sustainable and effective long-term conservation of biodiversity or use of available resources (Cumming & Cumming, 2003). Information concerning food habits is thus vital in formulating management strategies, at both species and ecosystem levels (Mills, 1992; Miquelle *et al*., 1996; Borah *et al*., 2009).

The Dhole or Asiatic wild dog (*Cuon alpinus*) is a pack-living predator widespread in Asian forest regions. It is classified as Endangered by the IUCN, the population being estimated at fewer than 2500 mature individuals remaining in the wild with a declining population trend which is expected to continue (Durbin *et al*., 2008). Despite their high conservation priority status, information concerning their ecology is still limited. Many studies concerning diet profile and behavior have been undertaken, but these were limited to the mainland of Asia including Bhutan (2 publications), India (19 publications), Laos, Malaysia and Thailand (1 publication) (Hayward *et al*., 2014), with none from Indonesia. The results of prior research show that the dhole's prey varies in size and weight, from less than 2.5 kg to more than 100 kg (Karanth & Sunquist, 1995; Grassman *et al*., 2005; Andheria *et al*., 2007; Kawanishi & Sunquist, 2008; Wang & Macdonald, 2009; Thinley *et al*., 2011). There is not only variability in size, but the di*et al*so shows great variety in species depending on what prey is available. For example, in India, dholes preyed most frequently on sambar (*Cervus unicolor*), chital (*Axis axis*), muntjak (*Muntiacus*), hares and other small prey (Cohen *et al*., 1978; Johnsingh, 1992; Karanth & Sunquist, 1995, 2000; Andheria *et al*., 2007; Borah *et al*., 2009), in Bhutan, sambar, muntjak, serow (*Capricornis*) and Goral (*Naemorhedus*) (Wang & Macdonald, 2009; Thinley *et al*., 2011), in Thailand, muntjak, wild pig (*Sus*), sambar and hog deer (*Axis porcinus*) (Grassman *et al*., 2005; Steinmetz *et al.*, 2013), and in Peninsular Malaysia, the lesser mouse-deer (*Tragulus kanchil*) (Kawanishi & Sunquist, 2008), confirming that prey availability varies from place to place (Venkataraman & Johnsingh, 2004). Thus more studies on the food habits across the range are necessary to understand the foraging ecology of this species, which has disappeared from much of its former range (Borah *et al*., 2009). Since geographical variation influences dietary variation for dholes and there is no information from Indonesia, we therefore conducted a study on the feeding habits of dholes in Baluran National Park (BNP), East Java, Indonesia. Previous research in BNP has been limited to studies on the population status of the dhole and its prey (Nurvianto *et al*., 2015c), anthropogenic influences and habitat (Nurvianto *et al*., 2015b), and den ecology and movement patterns (Nurvianto *et al*., 2015a). The feeding habits of the dhole and its implication for this species' conservation are discussed in this paper.

Materials and Methods

This study was carried out in Baluran National Park (BNP; Fig. 1), located in the northeast of Java at 70029′10″–70055′55″ S and 113029′10″–113039′10″ E (area 25,000 ha). Altitudes in the park range from sea level in coastal areas in the northern and eastern parts to 1,268 m above sea level at the peak of Mount Baluran in the middle of the park (Winnasis *et al*., 2011). The park is characterized by a monsoon climate with a long dry season from April to November; the annual precipitation ranges from 900–1,600 mm and mostly falls from December to January (Pudyatmoko & Djuwantoko, 2006; Hernowo *et al*., 2011). During the driest months (August–November) the precipitation is close to zero (Pudyatmoko *et al*., 2007). The habitat types found in the park are costal forest, mangrove forest, ephemeral wetland, savanna, shrubland, primary forest, secondary forest, *Acacia nilotica* stands, managed forests, and settlements. The park is home to large herbivores including banteng (*Bos javanicus*), feral buffalo (*Bubalus bubalis*), Javan deer (*Rus timorensis*), muntjac (*Muntiacus muntjak*) and wild boar (*Sus vittatus*), with the only large carnivore other than the dhole being the leopard (*Panthera pardus*) (Pudyatmoko & Djuwantoko, 2006; Pudyatmoko *et al*., 2007).

Scat analysis was employed to identify types of prey consumed by dholes in BNP. This method is an established tool for examining the diets of dholes (Johnsingh, 1992; Karanth & Sunquist, 1995; Andheria *et al*., 2007; Kawanishi & Sunquist, 2008; Borah *et al*., 2009; Wang & Macdonald, 2009; Thinley *et al*., 2011; Selvan *et al*., 2013a, b), and has an advantage over other techniques such as examination of gut content or direct observation of feeding because of the relative ease of obtaining samples and the non-invasive nature of sampling procedures (Andheria *et al*., 2007). The scats were collected by establishing a 287.5 km transect (Thinley *et al*., 2011), which was further divided into 201 transects with a 500 m space between transects (Morrison *et al*., 2001; Fig. 1). Scats which were found beyond the established transect were also collected. The fieldwork was conducted by two teams, each consisting of three surveyors experienced in recognizing dhole scats and mammal signs in general. Dhole scats were easily identified because these animals tend to defecate together in latrines (Johnsingh, 1982; Karanth & Sunquist, 1995; Durbin *et al*., 2004; Thinley *et al*., 2011; Kamler *et al*., 2012), a phenomenon not reported for sympatric domestic dogs or Asiatic jackals (*Canis aureus*) (Cohen *et al*., 1978), and the scat identification was confirmed by their distinctive odor, appearance and presence of dhole tracks near the collection site (Cohen *et al*., 1978; Johnsingh, 1992; Karanth & Sunquist, 1995; Selvan *et al*., 2013b). Once scats were found, they were collected and stored in an airtight plastic bag (Selvan *et al*., 2013a) and the locations of the scats were recorded using GPS Garmin 76 CSX. Only scats which were clearly identifiable were collected. As stated above, dholes hunt, feed, and defecate together in latrines (Johnsingh, 1982; Karanth & Sunquist, 1995; Durbin *et al*., 2004; Thinley *et al*., 2011; Kamler *et al*., 2012), so that individual latrines contained scats that nearly always have the same content, suggesting they came from the same feeding event (Thinley *et al*., 2011). Hence, as a general rule, only one scat from each latrine was collected to help ensure that scats were from independent feeding events (Kamler *et al*., 2012). All feeding events which were opportunistically encountered during the fieldwork were also recorded.

Figure 1: Map of study area in the Baluran National Park; dots represent the distribution of dhole's scats and lines represent the distribution of line transects.

The scats were subsequently washed in running water through 0.8 mm and 0.1 mm mesh sieves in order to retain the smallest items (Domenico *et al.*, 2012). The sieved prey remains, grass, and soil were then oven dried in thin paper bags at 70 °C for 2 days to avoid fungal growth (Borah *et al*., 2009), and stored and labelled an airtight bags. Prey items were identified through hairs in the scats and compared with hair from collection references, identified by color, length, thickness and medullary configuration (Borah *et al*., 2009; Karanth & Sunquist, 1995; Selvan *et al*., 2013a). The reference hairs were collected from specimens held at BNP, Gembira Loka Zoo and PASTY (animal market of Yogyakarta-Indonesia). The remains of mammals (bones, nails, claws, and skins), birds (feathers and bones), reptiles (scales, bones) and insects (exoskeletal parts) were identified macroscopically.

Frequency of occurrence and relative biomass of prey consumed and relative number of prey individuals consumed were analysed (Karanth & Sunquist, 1995; Andheria *et al*., 2007; Borah *et al*., 2009; Thinley *et al*., 2011; Selvan *et al*., 2013a, b). The frequency of occurrence is commonly used to measure prey intake and composition. The smaller prey types have greater surface area in relation to volume, and so will occur more frequently in the predator scats compared to the larger prey types and lead to overestimation of the proportion of small prey and underestimation of that of large prey in the diet (Andheria *et al*., 2007). To solve this problem, previous studies on dholes' feeding habits (Karanth & Sunquist, 1995, 2000; Andheria *et al*., 2007; Borah *et al*., 2009; Thinley *et al*., 2011; Selvan *et al*., 2013a, b) have generated a regression equation for estimating the relative contribution of prey biomass to the dhole diet using a correction factor (Floyd *et al*., 1978) by assuming that the dhole has a similar digestibility to wolves. The equation is $Y_i = 0.035 + 0.02X_i$, where X_i is the average live weight of a prey species *i* and Y_i is the weight of consumed prey species *i* per field collectible scat. The relative biomass can be measured using the formula $D_i = (A_i \times Y_i) \times 100 / \Sigma (A \times Y)$, where D_i is the relative biomass of species *i* (in percent) or proportion of meat of species *i* in the diet and A_i is the frequency of occurrence species *i* in the diet (in percent). The relative number of a prey species consumed can be measured using formula $E_i = (D_i / X_i) \times 100 / \Sigma (D / X)$, where E_i is relative number of prey species *i* consumed (in percent) or the proportion of number of prey species *i* taken among all species.

Results and Discussion

***Identification of prey*:** The results of the macroscopic analysis of the 54 scats showed that the scats contained mammal hair (F=54), bird feathers (F=6), reptile scales (F=12), insect exoskeletons (F=18) and bones of small mammals (F=40) (Table 1). Vegetable matter was found in the scats, including grass (*Imperata cylindrica*) and seeds of *Ziziphus mauritiana*, in 16 and 4 scats, respectively. From their specific characteristics, the insect exoskeletons were identified as being from the orders Coleoptera (beetles), Hymenoptera (ants, bees, wasps), and Orthoptera (grasshoppers and crickets) (Gillott, 2005). Nineteen mammal hairs and bird feathers were identified in the scats. From the total scats, 7.4% (n=4) contained a single prey species, 57.4% (*n*=31) contained two species, 25.9% (*n*=14) contained three species, 5.6% (*n*=3) contained four species and 3.7% (*n*=2) contained five species (Fig. 2). In terms of frequency of occurrence, buffalo had the highest proportion (A=35.2%) in the diet, followed by *Rattus tiomanicus* (A=31.5%) and *Tupaia glis* (A=31.5%) (Appendix 1). The species which had the highest biomass contribution in diet was buffalo (D=57.23%), followed by banteng (D=28.85%) and Javan rusa (D=6.37%) (Fig. 3). When the contributions of all of the ungulates (*i.e.* banteng, buffalo, Javan deer, wild boar and muntjac) in diets were combined, they provided 95.17% of the biomass consumed by dholes in BNP. Ungulates are thus the major prey species.

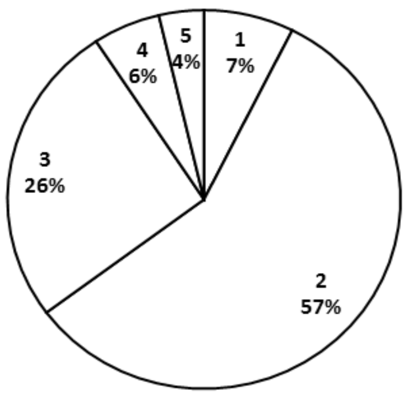

Figure 2: The proportion of the number of prey species found in each scat, which the upper number represent the number of species found in single scat (i.e. 1, 2, 3, 4 or 5) and the lower number represent the percentage number of the scats.

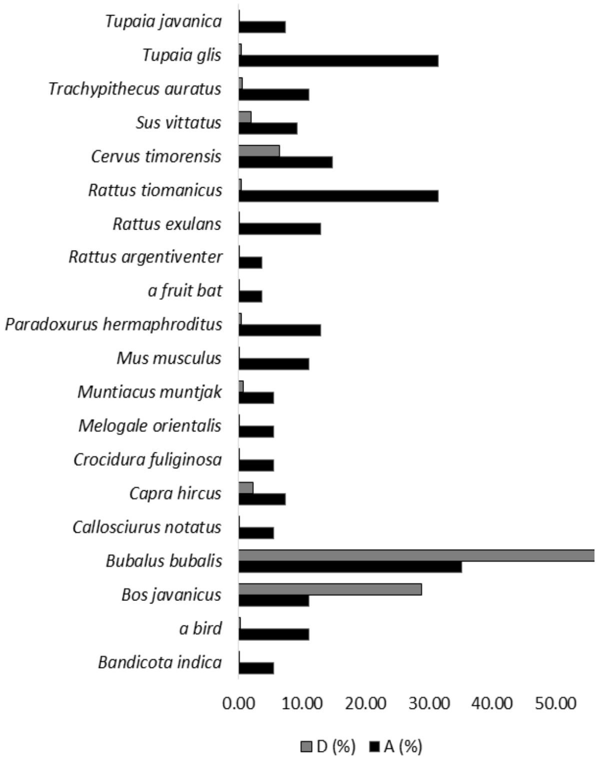

Figure 3: Frequency of occurrence (A) and prey biomass contribution (D) of dhole, based on scats.

***Frequency of different types of prey*:** Our research shows that the dhole in the BNP ecosystem has a wide food spectrum, consisting of at least 20 species. The consumed prey species were more diverse compared to that found for dholes at the other study sites (Appendix 2). Moreover, the presence of more of one species in most of the single scats was also high (92.6%). Prey sizes ranged from small animals (insects, reptiles, and small mammals) to large mammals (banteng, buffalo, rusa) in contrast to most previous research (Johnsingh, 1992; Karanth & Sunquist, 1995; Andheria *et al*., 2007; Kawanishi & Sunquist, 2008; Borah *et al*., 2009; Wang & Macdonald, 2009; Thinley *et al*., 2011; Selvan *et al*., 2013a, b). The frequency of occurrence of small mammals in the diet in BNP was relatively high (55%), mostly consisting of rodents (29%) as was also reported in the Khangchendzonga Biosphere Reserve in Sikkim, a small mountainous state in India (Bashir *et al*., 2013). The presence of small mammals and bird species in the dhole's diet is probably due to the species' pack hunting strategy and its ability to flush out and hunt the smaller and more cryptic prey species (Venkataraman, 1996; Kumaraguru *et al*., 2011; Bashir *et al*., 2013), most likely on the way to a hunt for larger prey (Kumaraguru *et al*., 2011). The occurrence of the nocturnal species (*Bandicota indica*, *Crocidura fuliginosa*, *Melogale orientalis*, *Mus musculus*, *Paradoxurus hermaphroditus,* fruit bata (family Pteropodidae), *Rattus argentiventer*, *Rattus exulans*, *Rattus tiomanicus*) in the scats suggested that dholes might be actively hunting at night, even though their contribution to the dhole's diet is low.

Table 1: The frequency (F) and proportion (%) of plant and animal material in dhole scats.

Scats content	F	Proportion (%)
Mammal hairs	54	100
Bird feathers	6	11.11
Reptile scales	12	22.22
Insects exoskeletons	18	33.33
Animals bones	40	74.07
Grasses	16	29.63
Seeds	4	7.41

***Predation on domestic livestock*:** Ungulates are the most important prey in the diet (Johnsingh, 1992; Karanth & Sunquist, 1995; Grassman *et al*., 2005; Andheria *et al*., 2007; Borah *et al*., 2009; Wang & Macdonald, 2009; Thinley *et al*., 2011; Selvan *et al*., 2013a, b; Steinmetz *et al*., 2013; Hayward *et al*., 2014): in this study, more than 95% of the biomass. Buffalo was the most dominant ungulate in the diet. Dholes have been reported to kill banteng, which affects their herd size, composition, sex ratio and sexual segregation (Pudyatmoko, 2005) and has been the major cause of the banteng's population decline in BNP (Pudyatmoko *et al*., 2007). The banteng's contribution to the dhole's diet amounts to 28.85% of the total biomass consumed, but, given the presence of illegal hunting in BNP (Nurvianto *et al*., 2015b), the role of dholes in the decline of the banteng population is still questionable, and it is plausible that dholes are also scavengers of banteng carcasses left by the illegal poachers. Generally, in the case of a generalist predator such as the dhole, feeding on multiple prey with no particular preference among them, the predation on different prey species will depend on their abundance (Sundararaj *et al*., 2012), while the banteng population abundance in BNP is low (Nurvianto *et al*., 2015c). This implies that further investigation of illegal poaching activities inside the park is necessary to develop management and conservation strategy for both species.

Hunting strategies: A predator has to evolve numerous time tested strategies against several ecological constraints such as prey size, prey behavior and habitat to secure prey at regular intervals necessary for its survival and procreation (Johnsingh, 1992). Observations in BNP have shown that dholes have developed their hunting strategies to hunt in the areas that have high levels of human activity. Based on our observations, when they hunted in the morning and made their kill in such an area (e.g. near ranger barracks or ecotourism points of interest), they did not rapidly consume all of the prey in the single event but left some part of the remaining carcass at the kill site and went back at night, when human activity was low or absent. Between the time when they left the carcass and when they returned to it, they were likely to hunt other animals (e.g. small mammals, insects, birds and reptiles) as a supplement to their diet. As a result of this behavior, the dholes produce scats which contain more of one species in a single scat. The ability to defend the kill from other predators and scavengers is crucial for the completion of a successful hunt and to gain maximum energy from the kill (Bailey *et al*., 2013). Rapid consumption and successful defense of a kill reduces the number of kills necessary, and consequently their energetic cost as well as the risks linked to the hunt (e.g. accident, predator encounter, death of pups left behind) (Courchamp & Macdonald, 2001). Indications are that the occurrence of kleptoparasitism in this park was very low. Nonetheless, this study is limited to a single season and one protected area. Further study should be extended in space and time to understand the foraging ecology of dholes in Java.

***Consequences for conservation*:** The presence of herding activities in BNP provides alternative prey for dholes but at the same time it brings complications to the conservation situation for this wild dog. The dhole is known as an opportunistic hunter; preying on whatever animals they encounter (Khatiwada *et al*., 2011). On several occasions, dholes also preyed on domesticated animals (sheep and cattle). The occurrence of many illegal herding practices in the park (Nurvianto *et al*., 2015b) facilitates this, as is also reported to occur in India (Cohen *et al*., 1978; Johnsingh, 1992; Selvan *et al*., 2013b; Srivathsa *et al*., 2014), Bhutan (Wang & Macdonald, 2009; Thinley *et al*., 2011), and Nepal (Khatiwada *et al*., 2011). The presence of domesticated ungulates inside the park, competitors for forage, is a cause of reduced body condition, reproductive rates, and survival of native ungulate species (Sundararaj *et al*., 2012). The decline of native prey populations will be followed by the disappearance of the predator, or the predator may switch its prey preference to the domesticated animals available in their territory. Hence the occurrence of domesticated animals inside the BNP will have a negative impact on the dhole’s conservation due to the loss of native prey and the increase in conservation costs (e.g. to compensate farmers for livestock depredation) (Sundararaj *et al*., 2012), and the potential for conflict resulting in the dhole’s illegal culling, cases of which have been reported to occur in Java in the colonial era (Hoogerwerf, 1970), in Bhutan (Wangchuk, 2004; Johnsingh *et al*., 2007), in India (Fox, 1984; Babu & Venkataraman, 2001), and in Nepal (Khatiwada *et al*., 2011). In the long term, the presence of domestic animals will affect the behavior of native ungulates, making native ungulates less vigilant in the places where domestic ungulates occur (Sundararaj *et al*., 2012), and rendering them vulnerable to illegal hunting, an illegal activity which still actively occurs in BNP (Nurvianto *et al*., 2015b). Moreover, herding activities have been reported to have negative effects on the presence of dholes and might be one factor in their decline to endangered status (Srivathsa *et al*., 2014; Nurvianto *et al*., 2015b). Consequently, the ability to manage the illegal herding activities is necessary to conserve dholes, their prey, and the BNP ecosystem.

Conclusion

We believe that our research finding has significance for the management of the dhole and its prey in Java, particularly in BNP. We have found that the dhole in BNP has a wide food spectrum and is an opportunistic predator. They prey on animals which are available within their territory, including domesticated ungulates (livestock), and their generalist and opportunistic behavior in the face of intensive herding activities within the park would place them in danger due to the potency of livestock depredation. Livestock depredation might be reduced or avoided if the availability of native prey, especially ungulates, was maintained by habitat protection and better livestock management (Wang & Macdonald, 2009). We conclude that in order to conserve the dhole and its prey, the management of BNP should formulate a policy to regulate herding activities within the park, both by restricting the activity as well as by tight law enforcement.

Acknowledgements
This first author was supported by a personal DAAD (Deutscher Akademischer Austauschdienst) scholarship. The study was also supported by the Wildlife Ecology and Management Laboratory-Faculty of Forestry at the Universitas Gadjah Mada. We would like to thank the staff of the Baluran National Park, especially the Head of the National Park, Emy Endah Suwarni, for granting us a research permit, and the ranger Siswanto for his field assistance. We would also like to thank Saidi, Solikin, Fauzi Hamdan, Arief Budiman, Yasmine Alwie and Lena Soumpasis for their assistance with field work, Kuna Aji for assistance with mapping, and Kurnia Lathifiana for assistance with scat analysis.

Literature cited

Agungpriyono, S., D. L. Kusindarto, C. Nisa, E. Hondo, M. Kurohmaru, and J. Yamada, 1999. Morphological study of the intestine of the Java treeshrew (*Tupaia javanica*). *Media Veteriner*, 6: 15–21.

Andheria, A. P., K. U. Karanth, and N. S. Kumar, 2007. Diet and prey profiles of three sympatric large carnivores in Bandipur Tiger Reserve, India. *Journal of Zoology*, 273: 169–175.

Babu, V. N. and A. Venkataraman, 2001. Dhole depredation and its consequences on the carnivore community in Arunachal Pradesh, Northeast India. *In*: Canid Biology and Conservation Conference, Oxford University: 323–335.

Bailey, I., J. Myatt, and A. Wilson, 2013. Group hunting within the carnivora: physiological, cognitive and environmental influences on strategy and cooperation. *Behavioral Ecology and Sociobiology*, 67: 1–17.

Bashir, T., T. Bhattacharya, K. Poudyal, M. Roy, and S. Sathyakumar, 2013. Precarious status of the endangered dhole *Cuon alpinus* in the high elevation Eastern Himalayan habitats of Khangchendzonga Biosphere Reserve, Sikkim, India. *Oryx*, 48: 125–132.

Borah, J., K. Deka, S. Dookia, and R. P. Gupta, 2009. Food habits of dholes (*Cuon alpinus*) in Satputra Tiger Reserve, Madya Pradesh, India. *Mammalia*, 73: 85–88.

Chaisiri, K., V. Herbreteau, A. Ribas, and S. Morand, 2010. A study of great bandicoot (*Bandicota indica*) and their gastrointestinal helminth from Northern and Northeastern Thailand. *Sciences Page of the Year* (Bangkok), 10: 163–171.

Cohen, J. A., M. W. Fox, A. J. T. Johnsingh, and B.D. Barnett, 1978. Food habits of the dhole in south India. *The Journal of Wildlife Management*, 42: 933–936.

Courchamp, F. and D. W. Macdonald, 2001. Crucial importance of pack size in the African wild dog *Lycaon pictus*. *Animal Conservation*, 4: 169–174.

Cumming, D. H. M. and G. S. Cumming, 2003. Ungulate community structure and ecological processes: body size, hoof area and trampling in African savannas. *Oecologia*, 134: 560–568.

Domenico, G. D., E. Tosoni, L. Boitani, and P. Ciucci, 2012. Efficiency of scat-analysis lab procedures for bear dietary studies: the case of the Apennine brown bear. *Mammalian Biology*, 77: 190–195.

Durbin, L. S., S. Hedges, J. W. Duckworth, M. Tyson, A. Lyenga, and A. Venkataraman, 2008. *Cuon alpinus*. The IUCN Red List of Threatened Species. Version 2014.3 <www.iucnredlist.org> accessed 13 April 2015.

Durbin, L. S., A. Venkataraman, S. Hedges, and W. Duckworth, 2004. Dhole (*Cuon alpinus*). *In:* Sillero-Zubiri, C., M. Hoffmann, and D. W. Macdonald (eds). *Canids: foxes, wolves, jackals and dog. Status survey and conservation action plan*. IUCN/SSC Canid Specialist, Gland, Switzerland, and Cambridge, UK. 210–219.

Floyd, T. J., L. D. Mech, and P. A. Jordan, 1978. Relating wolf scat content to prey consumed. *The Journal of Wildlife Management*, 42: 528–532.

Fox, M. W., 1984. *The Whistling Hunters: The field studies of Asiatic wild dog (Cuon alpinus)*. State University of New York Press, New York: 102–115.

Gillott, C., 2005. *Entomology*. Third Edition. Springer, Netherlands: 184–351.

Grassman, L. I. J., M. E. Tewes, N. J. Silvy, and K. Kreetiyutanont, 2005. Spatial ecology and diet of the dhole *Cuon alpinus* (Canidae, Carnivora) in north central Thailand. *Mammalia*, 69: 11–20.

Hayward, M. W., S. Lyngdoh, and B. Habib, 2014. Diet and prey preferences of dhole (*Cuon alpinus*): dietary competition within Asia's apex predator guild. *Journal of Zoology*, 294: 255–266.

Hernowo, J. B., A. Mardiastuti, H. S. Alikodra, and C. Kusmana, 2011. Behavior ecology of the Javan green peafowl (*Pavo muticus muticus* Linnaeus 1758) in Baluran and Alas Purwo National Parks, East Java. *HAYATI Journal of Biosciences*, 18: 164–176.

Hoogerwerf, A., 1970. *Udjung Kulon: The Land of the Last Javan Rhinoceros*. E. J. Brill, Leiden, Netherlands: 364–386.

Johnsingh, A. J. T., 1982. Reproduction and social behaviour of the dhole, *Cuon alpinus* (Canidae). *Journal of Zoology*, 198: 443–463.

Johnsingh, A. J. T., 1992. Prey selection in the three large sympatric carnivores in Bandipur. *Mammalia*, 56: 517–526.

Johnsingh, A. J. T., D. Yonten, and S. Wangchuck, 2007. Livestock-dhole conflict in Western Bhutan. *Journal of Bombay Natural History Society*, 104: 201–202.

Kamler, J. F., A. Johnson, C. Vongkhamheng, and A. Bousa, 2012. The diet, prey selection, and activity of dholes (*Cuon alpinus*) in northern Laos. *Journal of Mammalogy*, 93: 627–633.

Karanth, K. U. and M. E. Sunquist, 1995. Prey selection by tiger, leopard and dhole in tropical forest. *The Journal of Animal Ecology*, 64: 439–450.

Karanth, K. U. and M. E. Sunquist, 2000. Behavioural correlates of predation by tiger (*Panthera tigris*), leopard (*Panthera pardus*) and dhole (*Cuon alpinus*) in Nagarahole, India. *Journal of Zoology*, 250: 255–265.

Kawanishi, K. and M. E. Sunquist, 2008. Food habit and activity patterns of the Asiatic golden cat (*Catapuma temminckii*) and dhole (*Cuon alpinus*) in a primary rainforest of Peninsular Malaysia. *Mammal Study*, 33: 173–177.

Khatiwada, A. P., K. D. Awasthi, N. P. Gautam, S. R. Jnawali, N. Subedi, and A. Aryal, 2011. The pack hunter (dhole): received little scientific attention. *Nepal Journal Online*, 4: 8–13.

Kitamura, S. and P. Poonswad, 2013. Nutmeg-vertebrate interactions in the Asia-Pacific region: importance of frugivores for seed dispersal in Myristicaceae. *Tropical Conservation Science*, 6: 608–636.

Kumaraguru, A., R. Saravanamuthu, K. Brinda, and S. Asokan, 2011. Prey preference of large carnivores in Anamalai Tiger Reserve, India. *European Journal of Wildlife Research*, 57: 627–637.

Lee, C. H., 1997. Field rodent population abundance and cocoa crop loss. *Journal of Tropical Agriculture and Food Science*, 25: 25–41.

Long, J. L., 2003. *Introduced mammals of the world: their history, distribution and influence*. CSIRO Publishing, Oxon, UK: 133–465.

Meiri, S., D. Simberloff, and T. Dayan, 2005. Insular carnivore biogeography: island area and mammalian optimal body size. *The American Naturalist*, 165: 505–514.

Mills, M. G. L., 1992. A comparison of methods used to study food habits of large African carnivores. *In:* McCullough, D. and R. Barrett (eds). *Wildlife 2001: Populations*. Springer Netherlands: 1112–1124.

Miquelle, D. G., E. N. Smirnov, H. G. Quigley, M. G. Hornocker, I. G. Nikolaev, and E. N. Matyushkin, 1996. Food habits of amur tigers in Sikhote-Alin Zapovednik and the Russian Far East, and implications for conservation. *Journal of Wildlife Research*, 1: 138–147.

Morrison, M. L., W. M. Block, M. D. Strickland, and W. L. Kendall, 2001. *Wildlife Study Design*. Springer-Verlag New York, Inc., New York.

Nurvianto, S., M. A. Imron, and S. Herzog, 2015a. Activity patterns and behaviour of denning dhole (*Cuon alpinus*) in a dry deciduous forest of East Java, Indonesia. *Bulletin of Environment, Pharmacology & Life Sciences*, 4.

Nurvianto, S., M. A. Imron, and S. Herzog, 2015b. The influence of anthropogenic activities and availability of prey on the distribution of dholes in a dry deciduous forest of East Java, Indonesia. *Asian Journal of Conservation Biology*, 4: 26–36.

Nurvianto, S., M. A. Imron, and S. Herzog, 2015c. The population status of the dhole *Cuon alpinus* and its prey in Baluran National Park, East Java, Indonesia. Submitted in *Mammalian Biology*.

Pudyatmoko, S., 2005. Does the banteng have a future in Java? Challenges of the conservation of a large herbivore in a densely populated island. *In:* A synthesis of contributions to the knowledge marketplace, 3rd IUCN World Conservation Congress the World Conservation Union, Gland, Switzerland and Cambridge, UK: 1–6.

Pudyatmoko, S. and Djuwantoko, 2006. Sex ratio, herd size and composition and sexual segregation in banteng in the Baluran National Park, Indonesia. *Journal of Biological Science*, 6: 370–374.

Pudyatmoko, S., Djuwantoko, and Y. Sabarno, 2007. Evidence of banteng (*Bos javanicus*) decline in Baluran National Park, Indonesia. *Journal of Biological Science*, 6: 854–859.

Ramesh, T., R. Kalle, K. Sankar, and Q. Qureshi, 2012. Dietary partitioning in sympatric large carnivores in a tropical forest of Western Ghats, India. *Mammal Study*, 37: 313–321.

Selvan, K. M., N. Gokulakkannan, and N. Sridharan, 2013a. Food habits of dhole *Cuon alpinus* in Kalakad-Mundanthurai Tiger Reserve in Tamil Nadu, India. *Asian Journal of Conservation Biology*, 2: 69–72.

Selvan, K. M., G. G. Veeraswami, S. Lyngdoh, B. Habib, and S. A. Hussain, 2013b. Prey selection and food habits of three sympatric carnivores in a tropical lowland forest of the eastern Himalayan biodiversity hotspot. *Mammalian Biology*, 78: 296–303.

Srivathsa, A., K. K. Karanth, D. Jathanna, N. S. Kumar, and K. U. Karanth, 2014. On a dhole trail: examining ecological and anthropogenic correlates of dhole habitat occupancy in the Western Ghats of India. *PLoS One*, 9: e98803.

Steinmetz, R., N. Seuaturien, and W. Chutipong, 2013. Tigers, leopards, and dholes in a half-empty forest: assessing species interactions in a guild of threatened carnivores. *Biological Conservation*, 163: 68–78.

Sundararaj, V., B. E. McLaren, D. W. Morris, and S. P. Goyal, 2012. Can rare positive interactions become common when large carnivores consume livestock? *Ecology*, 93: 272–280.

Thinley, P., J. F. Kamler, S. W. Wang, K. Lham, U. Stenkewitz, and D. W. Macdonald, 2011. Seasonal diet of dholes (*Cuon alpinus*) in northwestern Bhutan. *Mammalian Biology*, 76: 518–520.

Venkataraman, A. B., 1996. Nature watch. The dhole or Asiatic wild dog. *Resonance*, 1: 74–79.

Venkataraman, A. B., R. Arumugam, and R. Sukumar, 1995. The foraging ecology of dhole (*Cuon alpinus*) in Madumalai Sanctuary, southern India. *Journal of Zoology*, 237: 543–561.

Venkataraman, A. B. and A. J. T. Johnsingh, 2004. The behavioural ecology of dholes in India. *In:* Macdonald D. W. and C. Sillero-Zubiri (eds). *The Biology and Conservation of Wild Canids.* Oxford University Press, New York: 323–335.

Wang, S. W. and D. W. Macdonald, 2009. Feeding habits and niche partitioning in a predator guild composed of tigers, leopards and dholes in a temperate ecosystem in central Bhutan. *Journal of Zoology*, 277: 275–283.

Wangchuk, T., 2004. Predator-prey dynamics: the role of predators in the control of problem species. *Journal of Bhutan Studies*, 10: 68–89.

Yasuma, S., L. Apin, and F. T. Y. Yu, 2003. Mammals of Crocker Range. Park Management Component BBEC Programme Sabah Parks, Sabah, Malaysia: 16.

Appendix 1: Frequency (F), frequency of occurrence (A), live weight prey (X), relative biomass consumed (D), and relative number of prey individuals consumed by dholes in BNP based on scat analysis from 54 scats.

Common Name / Scientific Name	*F*	*A* (%)	*X* (kg)	References	Y	A*Y	D	D/X	E
Bandicoot (*Bandicota indica*)	3	5.56	0.40	Chaisiri *et al*., 2010)	0.04	0.21	0.07	0.17	0.89
A bird species	6	11.11	1.00		0.05	0.56	0.18	0.18	0.94
Banteng (*Bos javanicus*)	6	11.11	400.00	Long, 2003	8.03	89.22	28.85	0.07	0.38
Asian water buffalo (*Bubalus bubalis*)	19	35.19	250.00	Long, 2003	5.03	176.98	57.23	0.23	1.20
Oriental squirrel (*Callosciurus notatus*)	3	5.56	0.20	Lee, 1997	0.03	0.19	0.06	0.31	1.60
Domestic goat (*Capra hircus*)	4	7.41	47.00	Wang & Macdonald, 2009	0.97	7.19	2.32	0.05	0.26
Southeast Asian shrew (*Crocidura fuliginosa*)	3	5.56	0.01	Yasuma *et al*., 2003	0.03	0.17	0.05	4.53	23.65
Javan ferret-badger (*Melogale orientalis*)	3	5.56	0.85	Meiri *et al*., 2005	0.05	0.26	0.08	0.10	0.52
Indian muntjac (*Muntiacus muntjak*)	3	5.56	20.00	Andheria *et al*., 2007	0.43	2.39	0.77	0.04	0.20
House rat (*Mus musculus*)	6	11.11	0.03	Long, 2003	0.03	0.34	0.11	3.66	19.15
Asian palm civet (*Paradoxurus hermaphrodites*)	7	12.96	3.00	Long, 2003	0.09	1.17	0.38	0.13	0.66
A fruit bat (family Pteropodidae)	2	3.70	0.02		0.03	0.11	0.04	1.82	9.51
Rice field rat (*Rattus argentiventer*)	2	3.70	0.20	Long, 2003	0.03	0.13	0.04	0.20	1.06
Pacific Rat (*Rattus exulans*)	7	12.96	0.10	Long, 2003	0.03	0.41	0.13	1.34	7.01
Malayan wood rat (*Rattus tiomanicus*)	17	31.48	0.12	Lee, 1997	0.03	1.02	0.33	2.75	14.36
Javan deer (*Cervus timorensis*)	8	14.81	65.00	Long, 2003	1.33	19.70	6.37	0.10	0.51
Wild boar (*Sus vittatus*)	5	9.26	31.00	Long, 2003	0.65	6.02	1.95	0.06	0.33
Javan lutung (*Trachypithecus auratus*)	6	11.11	7.10	Kitamura & Poonswad, 2013	0.17	1.91	0.62	0.09	0.45
Common tree shrew (*Tupaia glis*)	17	31.48	0.13	Lee, 1997	0.03	1.03	0.33	2.55	13.34
Javan tree shrew (*Tupaia javanica*)	4	7.41	0.10	Agungpriyono *et al*., 1999	0.03	0.24	0.08	0.77	4.00
	131					309.24	100.00	19.14	100.00

Appendix 2: The consumed prey species that found for dholes at the other research sites

Research site		Prey species	Reference
Peninsular Malaysia		**5 species:** *Trachypithecus obscurus*, *Macaca nemestrina*, *Sciurid* sp., *Sus scrofa*, *Tragulus* sp.	Kawanishi & Sunquist, 2008
North central Thailand		**4 species:** *Sus scrofa*, *Muntiacus muntjak*, *Axis porcinus*, *Cervus unicolor*	Grassman *et al*., 2005
Bhutan	Central	**11 species:** *Cervus unicolor*, *Muntiacus muntjak*, *Bos gaurus*, a langur, *Nemorhaedus goral*, *Sus scrofa*, *Bos taurus*, *Bos grunniens*, *Equus caballus*, *Ovis aries*, *Canis familiaris*	Wang & Macdonald, 2009
	Northwestern	**6 species:** *Cervus unicolor*, *Capricornis sumatraensis*, *Muntiacus muntjak*, *Nemorhaedus goral*, *Sus scrofa*, *Bos taurus*	Thinley *et al*., 2011
Northern Laos		**9 species:** *Muntiacus muntjak*, *Cervus unicolor*, *Sus scrofa*, *Capricornis milneedwardsii*, *Ursus thibetanus*, a civet, *Arctonyx collaris*, *Atherurus macrourus*, a rodent	Kamler *et al*., 2012
India	Eastern Himalayas	6 species: *Muntiacus muntjak*, *Cervus unicolor*, *Bos gaurus*, *Sus scrofa*, *Bos taurus*, *Lepus* sp.	Selvan *et al*., 2013b
	Madhya Pradesh	**7 species:** *Cervus unicolor*, *Lepus nigricollis*, *Axis axis*, *Sus scrofa*, *Semnopithecus entellus*, *Muntiacus muntjak*, *Gallus gallus*	Borah *et al*., 2009
	Karnataka	**10 species:** *Cervus unicolor*, *Axis axis*, *Muntiacus muntjak*, *Tetracerus quadricornis*, *Tragulus meminna*, *Sus scrofa*, *Bos gaurus*, *Semnopithecus entellus*, *Lepus nigricollis*, *Cuon alpinus*	Andheria *et al*., 2007
	South	**4 species:** *Axis axis*, *Cervus unicolor*, *Bos taurus*, *Lepus nigricollis*	Venkataraman *et al*., 1995
	Southwestern	**11 species:** *Axis axis*, *Cervus unicolor*, *Bos gaurus*, *Sus scrofa*, *Muntiacus muntjak*, *Semnopithecus entellus*, *Tetracerus quadricornis*, *Tragulus meminna*, *Lepus nigricollis*, *Hystrix indica*, *Cuon alpinus*	Karanth & Sunquist, 1995
	Southern Western Ghats	**11 species:** *Cervus unicolor*, *Bos taurus*, *Sus scrofa*, *Bos gaurus*, *Nilgiritragus hylocrius*, *Semnopithecus entellus*, *Axis axis*, *Muntiacus muntjak*, *Tragulus meminna*, *Lepus nigricollis*, *Gallus sonneratii*	Selvan *et al*., 2013a
	Western Ghats	**16 species:** *Cervus unicolor*, *Axis axis*, *Bos gaurus*, *Sus scrofa*, *Semnopithecus entellus*, *Tragulus meminna*, *Bos taurus*, *Lepus nigricollis*, *Muntiacus muntjak*, a bird, *Herpestes erdwardsii*, *Herpestes* sp., a species of family Muridae, *Paradoxurus jerdoni*, *Viverricula indica*, an Insect	Ramesh *et al*., 2012