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Seasonal food habits of the endangered Indochinese leopard *Panthera pardus delacouri* in a protected area of North West Thailand

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Abstract. The Indochinese leopard *Panthera pardus delacouri* has experienced a sharp decline in numbers and distribution, especially in Thailand. We have analyzed its diet in Om Koi Wildlife Sanctuary of North West Thailand, where only wild prey species were present. Scats were collected during the dry-hot and the dry-cold seasons. The Indian muntjac appeared to be the staple of the leopard's diet, particularly in the dry-cold season, and consumed equally with the Indian wild boar in the dry-hot one. The occurrence of the Indochinese hog deer in the diet of the leopard in Om Koi represents the first detection record of this endangered species in North West Thailand, after being long extirpated. During the dry-hot season, poachers slashed and burnt portions of forest to flush game and to provide space for poppy fields. Muntjacs are sensitive to both forest fires and poaching, whereas Indian wild boar are resilient to disturbance, which may explain their alternation in diet.

Key words: diet, Indochinese hog deer, muntjac, slash and burn, wild boar

Species with wide distribution ranges show an ecological plasticity which allows them to adapt to a number of habitat types (Gaston 1994, Duncan et al. 2003). Environmental and climatic conditions influence the distribution of food resources which, in turn, determine dietary composition and diversity (Hill & Dunbar 2002, Soe et al. 2017). As a consequence, species with a broad distribution range may adapt to a number of trophic conditions, resulting in large niche breadths (e.g. the red fox *Vulpes vulpes*: Soe et al. 2017, the wildcat *Felis silvestris*: Lozano et al. 2006, the Eurasian badger *Meles meles*: Roper & Mickevicius 1995, Goszczyński et al. 2000).

The common leopard *Panthera pardus* is the most widely distributed large cat (females 30-60 kg, males 37-90 kg, Nowak 1991) in the world, from most of Sub-Saharan Africa to the Middle East, the Indian subcontinent and Southeastern Asia up to the Amur region of Eastern Russia (www.iucnredlist.org: accessed on the 2nd of February 2017). In spite of the great biological flexibility of this cat, most populations are currently isolated and decreasing, mainly because of human persecution, habitat fragmentation, prey loss and trophy hunting (Thorn et al. 2013, Selvan et al. 2014, Jacobson et al. 2016). As a consequence, this species is listed as "vulnerable" by the International Union for the Conservation of Nature (www.iucnredlist.org: accessed on the 2nd of February 2017, Jacobson et al. 2016). In South East Asia, especially in Thailand, the common leopard is rated as endangered because of high rates of deforestation and poaching for the wildlife trade (Jacobson et al. 2016, Rostro-Garcìa et al. 2016).

The main prey species of the common leopard range between 2 and 50 kg of body mass: over 150 species of wild mammals and birds have been reported in its diet throughout Africa (Hayward et al. 2006) and Asia (Lovari et al. 2013a). Furthermore, where the availability of large prey is the lowest (i.e. where lions and tigers are present: e.g. Karanth & Sunquist 2000, Hayward et al. 2006, Andheria et al. 2007, Lovari et al. 2015), common leopards may include in their diet small rodents (Johnson et al. 1993, Andheria et al. 2007), catfish *Clarias* sp. (Mitchell et al. 1965), amphibians/reptiles (Lovari et al. 2013a), freshwater crabs (Decapoda: Rabinowitz 1989) and even plant matter (Hoppe-Dominik 1984, Johnson et al. 1993). Leopards may be able to survive also where wild

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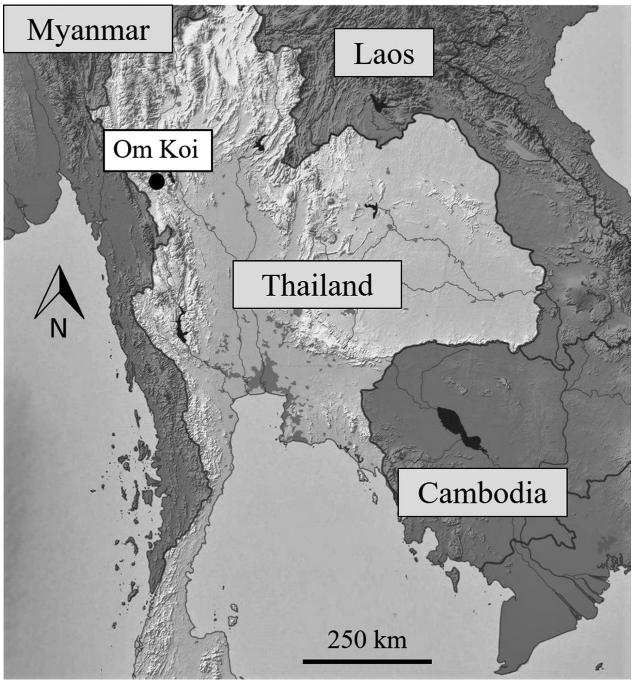

Fig. 1. Location of the Om Koi Wildlife Sanctuary, NW Thailand.

ungulates are absent, but livestock is present (Lovari et al. 2013b, for a review; Athreya et al. 2014, Shehzad et al. 2014, Chattha et al. 2015, Sujimoto et al. 2016). In our work, we have analyzed the diet of the Indochinese leopard *P. p. delacouri* in a protected area of South East Asia (Om Koi Wildlife Sanctuary), where domestic species were absent. The Om Koi Wildlife Sanctuary is a protected area (122400 ha) established in 1978 and located in North West Thailand (18°05′ N-98°26′ E, about 1580 m a.s.l., max. altitude: Mt. Doi Mon Jong, 1929 m a.s.l.) near the border with Myanmar, in Chiang Mai Province (Fig. 1).

This area was covered almost completely by an evergreen dry-Dipterocarp mountain forest mixed with Lauraceae (e.g. *Dipterocarpus turbinatus*, *D. costatus*, *D. alatus*, *Litsea* spp.: Sayer 1981). At the time of our study (1985-1986), grasslands (*Heteropogon contortus*, *Eulalia siamensis*) were scanty and mainly occurred on narrow mountain ridges or where humans had cleared the forest. Accordingly, the Om Koi Wildlife Sanctuary hosted one of the most intact evergreen forest communities in Northern Thailand and it was included amongst the national biodiversity hotspots (Pattanavibool & Dearden 2002). Amongst mammals, wild Asiatic elephants *Elephas maximus*, dusky langurs *Trachypithecus obscurus*, Malayan porcupines *Hystrix brachyura*, Chinese grey goral *Naemorhedus caudatus evansi*, Indian wild boar *Sus scrofa cristatus*, Indian muntjac *Muntiacus vaginalis* and the rare banteng *Bos javanicus* were present (Lovari & Apollonio 1993, Pattanavibool & Dearden 2002). The endangered Indochinese hog deer *Hyelaphus porcinus annamiticus* was very rare in Thailand, where it has been reintroduced at the end of the 1990s (Pattanavibool & Dearden 2002).

The Indochinese tiger *Panthera tigris corbettii* and the dhole *Cuon alpinus* were said to be occasionally present, but only during the rainy season (Ngampongsai C., *ex verbis*). Eight years later, Rabinowitz (1993) reported the presence of the tiger, but no sign of this species (e.g. its diagnostic scrapes and pugmarks) was detected during our field work. The largest carnivore in our study area was the Indochinese leopard, a subspecies at risk of extinction (Rostro-Garcìa et al. 2016). No information was available on the density of prey species and on their seasonal availability for predators.

Several small villages of hill tribes (Meo, Karen) occurred at the lower altitudes, living off the products of the forest and cultivating poppy fields through the "slash and burn" system (Lovari & Apollonio 1993).

The local climate was subtropical, with annual temperatures ranging between 22 and 36 °C (Chaiyarat et al. 1999) and three seasons (rainy season, largely

Table 1. Seasonal differences in the diet of the common leopard: occ. – occurrence; **P* < 0.01; NA – not applicable. B_{STA} – standardised Levin's index.

Prey species	Relative % occ.				Absolute % occ.		
	Total	Dry-hot season	Dry-cold season	*G*-test	Total	Dry-hot season	Dry-cold season
Dusky langur	8.6	6.3	9.8	2.4	9.1	6.3	11.8
Malayan porcupine	5.7	6.3	5.2	0.2	6.1	6.3	5.9
Chinese goral	8.6	12.5	5.2	3.6	12.5	5.9	9.1
Indian wild boar	28.6	34.3	21.5	6.9*	30.3	37.5	23.5
Indian muntjac	45.7	34.3	58.3	14.3*	48.5	37.5	58.8
Indochinese hog deer	2.9	6.3	0.0	NA	3.0	6.3	0.0
B_{STA}	0.45	0.56	0.29				

dominated by the monsoons: May-October; dry-cold season: November-January; dry-hot season: February-April – Lovari & Apollonio 1993, Chaiyarat et al. 1999).

In 1985-1986, one of us (SL) collected a total of 33 leopard scats (n = 16 in the dry-hot season, n = 17 in the dry-cold season) along the 8 km ridge of Doi Mon Jong. The ridge, where also scrapes and pugmarks of this species were found, was walked once/15 days, respectively during the dry-hot (April 1985) and the dry-cold (January 1986) seasons. A thorough, conservative selection of scats was made on the basis of different features (e.g. smell, position, size, contents, presence of pugmarks and scrapes) to decrease the risk of collecting scats of other species, e.g. civets, smaller cats, martens and Himalayan black bear *Ursus thibetanus*. No feature alone is species specific, but the complex of them can be quite effective. Mistakes may have occurred only with scats of the clouded leopard *Neofelis nebulosa*, which was exceedingly rare – if any – in the area (Ngampongsai C., *ex verbis*). Furthermore, the presence of own hair in scats of felids is commonly used to assess the identity of the cat species and we found only hair of the common leopard in our samples, whenever present.

Scats were preserved in nylon bags and labeled with the collection date. In the lab, scats were dissected, washed with hot water and further cleaned with carbon tetrachloride (Andheria et al. 2007, Chattha et al. 2015). Hair, remains of bones, ischial callosities of monkeys, quills and hooves were then isolated. Hair were mounted on glass slides following Chattha et al. (2015) and observed at the microscope. Hair scale imprints were created by using transparent nail varnish and observed at the stereomicroscopy at ×200 and ×400 magnifications (Ott et al. 2006). A hair reference collection was compiled including mammal species (wild and domestic ones) from captive animals at the Dusit Zoo in Bangkok to correctly identify prey items.

The absolute (number of occurrences of each food, when present/total number of scats ×100) and relative (number of occurrences of each food, when present/ total number of occurrences of all food items ×100) percentage of occurrence of each prey was calculated for both seasons (cf. Lucherini & Crema 1995); *G*-tests were applied to the number of prey remains detected within leopard scats, to study seasonal variation in the diet. The Bonferroni correction for multiple testing was applied (Simes 1986). The Levin's standardised index (B_{STA}) was used to assess trophic niche breadth (Krebs 1999): $B_{STA} = (B – 1)/(B_{max} – 1)$, where: "B" is the Levin's index, "B_{max}" is the total number of prey categories. B_{STA} varies between 0 (minimum breadth) and 1 (maximum breadth). The Levin's index (B) was calculated as $B = 1/\Sigma p_i^2$, where p_i is the proportion of each i-food item identified in every scat.

Biomass consumed was not estimated, because of the misleading flaws which affect this calculation (e.g. Chakrabarti et al. 2016, Lumetsberger et al.

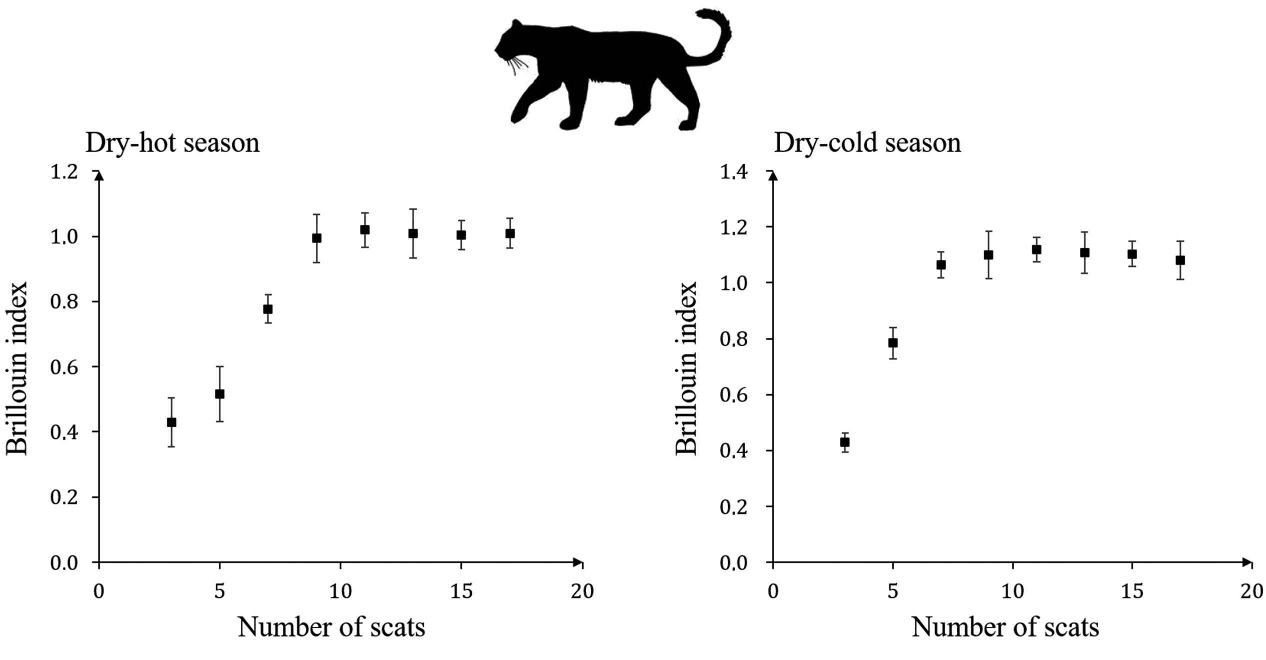

Fig. 2. Brillouin Diversity Index for the Indochinese leopard, for the dry-hot (left) and the dry-cold (right) season.

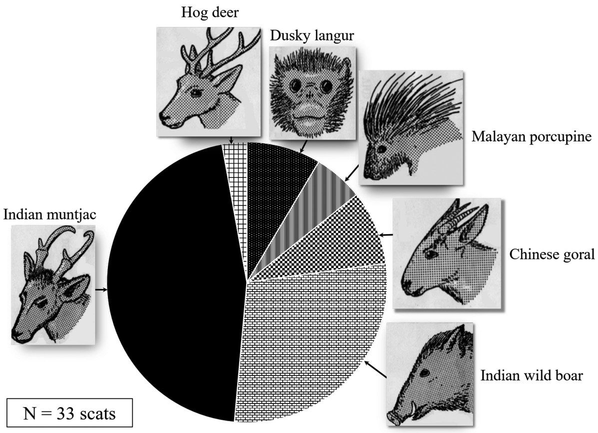

Fig. 3. Diet composition of the common leopard. The hooves of an adult and a fawn muntjac, presumably mother and offspring, were found in two scats out of 15, containing this deer species.

2017). Furthermore, it is usually impossible to know (i) whether a young/subadult/male/female has been preyed upon (body mass is normally quite different in different age classes and sexes, especially of polygynous ungulates); (ii) whether a predator scavenged from a carcass already partly eaten by other carnivores or from its own kill; (iii) whether it fed alone or with conspecifics, e.g. a female with cubs. As to the common leopard, the Brillouin Diversity Index (cf. Glen & Dickman 2006) has indicated that from 11-13 scats (Lovari et al. 2013a) to 15-17 (Lovari et al. 2015) are large enough samples to be representative of diet. As to our samples, the Brillouin Diversity Index (Fig. 2) indicated that eight samples were enough to provide the seasonal diet of the leopard in both periods. Of course, eight samples may still be inadequate for the detection of rare prey species, if any.

Our data provide only preliminary information on the food of leopards in North West Thailand, to be confirmed by further studies. Six prey species were used by the leopard in Om Koi (Fig. 3). The mean number of prey items per scat was 1.21, although most scats (71 %) contained one prey species only. The Indian muntjac was the staple of the diet (45.7 % occ.), followed by the Indian wild boar (28.6 % occ.) (Fig. 3). The trophic niche breadth (standardized Levin's index: B_{STA}) was 0.45 (Table 1). There were differences in diet between the dry-hot and the dry-cold seasons (Table 1). In particular, the muntjac was consumed more in the dry-cold season, whereas the wild boar showed the opposite pattern.

There are very few reports on the food habits of the common leopard in absence of ecological competitors (e.g. tiger, snow leopard, clouded leopard, wolf, dhole) in Asia (e.g. Kittle et al. 2017). Only when no competitor is present, a species can increase its prey spectrum and select preferred food resources (Stephens & Krebs 1986). We could not assess prey selection in our study area, because no information was available on prey abundance. Yet, our data can be useful to outline the use of prey of this cat in a competitor-free area.

In Asia, the common leopard tends to use mainly small prey species (2-25 kg: Lovari et al. 2013a, but see Odden & Wegge 2009, Kittle et al. 2017). Our results would confirm it, with the exception of the goral, although by just one kg (mean weight = 26 kg: Wasalai 2002) and the Indian wild boar (mean weight = 80 kg: Lovari et al. 2013a). In fact, the size of hooves of the wild boar found in 4-5 scats (i.e. ca. 50 % of scats containing this prey) suggested that mainly younger individuals (up to two years old) had been preyed upon. If only immature wild boar were preyed on (cf. Mattioli et al. 1995, Nores et al. 2008 for the wolf), their body mass would well fit in the "small prey" category.

If the rare banteng, a large bovine species (590-800 kg: Purwantara et al. 2011), is unlikely to be preyed on by the leopard, the only relatively large prey species locally available could have been adult wild boar and hog deer (mean weight = 68.5 kg: Lovari et al. 2013a). In Thailand, the Indochinese hog deer was thought to be extinct and its reintroduction started on the 1990s (Pattanavibool & Dearden 2002, Prasnai et al. 2012, www.iucnredlist.org: accessed on the 2nd of February 2017), some years after our scat samples were collected. Our data suggest that this species still survived to the mid-1980s, at least in the North West corner of Thailand.

While the muntjac was the staple of the diet in the dry-cold season, it was supplemented by the wild boar in the dry-hot one. This may be due to a local lower density of the muntjac during the dry-hot season in respect to the dry-cold one. In the former, when scats were collected (1985-1986), every year poachers used to slash and burn portions of forest to flush game, as well as to provide space for poppy fields (Lovari 1997, Pattanavibool & Dearden 2002). Lovari (2012: 16) reported 3.5 forest patches/km^2 in flames at the same time, over ca. 4 km^2, on April 1985. In fact, in over 40 years (1956-1996), the number of forest patches in Om Koi has nearly doubled, whereas the mean patch size has decreased by 42 %, because of human activities, suggesting an increasing level of forest fragmentation (Pattanavibool & Dearden 2002). One could expect that, in the last 15 years, the forest cover in Om Koi may have been reduced further, thus affecting the local herbivore community and, in turn, the availability of potential prey to the common leopard. A comparative study to ours would be desirable to assess whether the common leopard is still present and whether/how its food habits may have adapted.

Muntjacs are elusive, forest deer (Odden & Wegge 2007, Wegge & Mosand 2015, www.iucnredlist.org: accessed on 2nd February 2017), especially sensitive to both forest fires and poaching (Steinmetz et al. 2010), whereas wild boar are much more resilient to disturbance (Steinmetz et al. 2010, Rustam et al. 2012), which could explain the increase of muntjac predation in the dry-cold season in respect to the dry-hot one, when local disturbance by humans was high. If so, our data may support the view that heavy disturbance upsets the ecological relationships in the disturbed area, e.g. by removing directly and/or indirectly important components of the prey spectrum of the common leopard. On the other hand, our data may also suggest that leopards can adapt to changed circumstances by adjusting their diet accordingly.

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