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Interference avoidance by wild ungulates at a mineral lick, Central Kalimantan

Mineral licks are small, mineral-rich sites within forests that wildlife visit to supplement their mineral intake by licking or consuming soil (Montenegro 2004, Matsubayashi & Lagan 2014). These licks are essential sources of minerals such as sodium, potassium, calcium, and magnesium, which support osmoregulation, toxin neutralization, and the development of bones and muscles (Kreulen & Jager 1984, Brightsmith & Muñoz-Najar 2004, Abrahams 2012, Sim *et al*. 2020). Due to mineral deficiencies in plant foliage, wild herbivores often resort to geophagy (Ayeni 1972). The Belantikan Hulu area, within the Arabela landscape of the Schwaner Mountains in Central Kalimantan, Indonesia, comprises lowland forest dominated by Dipterocarpaceae species such as *Dipterocarpus fagineus* and *Shorea laevis*, along with *Eusideroxylon zwageri*. There are several active mineral licks in this landscape (Sadikin *et al*. 2009, Dewi *et al*. 2020, Wicaksono *et al*. 2022).

Camera traps have made wildlife monitoring at mineral licks more effective, allowing non-invasive and continuous observation (Kühl *et al*. 2011, Ancrenaz *et al*. 2012). Mammals like ungulates, primates, and rodents, as well as some birds, frequently visit mineral licks (Montenegro 2004, Link *et al*. 2011, King *et al*. 2016). Despite their small size, these sites can be biodiversity hotspots; for example, 28 medium-to-large mammal species, including Bornean clouded leopard (*Neofelis diardi borneensis*), were recorded at four mineral licks in Deramakot Nature Reserve, Sabah (Matsubayashi & Lagan 2014). In Belantikan Hulu, camera traps recorded 16 wild species at mineral licks, including ungulates, but no top predators such as the Bornean clouded leopard (Wicaksono *et al*. 2022). As a limited resource, mineral licks may be sites of ecological competition. This can be exploitation competition, where one species depletes resources used by another, or interference competition, involving direct exclusion (Putman 1994). Sympatric species may avoid such conflicts through spatial or temporal niche partitioning (Zanni *et al*. 2021). This study analyzes ungulate presence, temporal activity, and co-occurrence at a mineral lick in Belantikan Hulu to assess whether temporal partitioning suggests avoidance of interference. Ungulates, as frequent visitors, offer key insights into resource-sharing dynamics at these vital but scarce forest resources (Matsubayashi *et al*. 2007, Tobler *et al*. 2009). This study was conducted at the Penggaraman mineral lick (01°34'11.654"S, 111°21'50.148"E) in the Belantikan Hulu forest, Lamandau Regency, Central Kalimantan, Indonesia (Fig. 1).

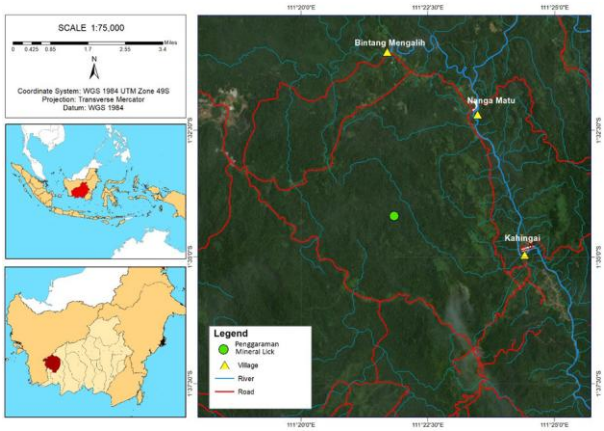

Figure 1. Map of the study area showing the location of Penggaraman Mineral Lick, Belantikan Hulu forest area, Central Kalimantan

The Belantikan landscape extends from the Arut Belantikan region to Bukit Rongga and

Bukit Perai in West Kalimantan, covering approximately 200,000 ha, including 43,000 ha of protected forest. Within this, PT Karda Traders has designated 1,040 ha as a banteng (*Bos javanicus*) conservation area. Belantikan Hulu is a biodiversity hotspot and a priority habitat for banteng and supports the largest Bornean Orangutan (*Pongo pygmaeus wurmbii*) population outside formal conservation areas (Sapari *et al*. 2018, Wich *et al*. 2004). Despite its ecological value, wildlife faces pressure from local hunting, with species like sambar (*Rusa unicolor*), bearded pig (*Sus barbatus*), and banteng commonly targeted (Dewi *et al*. 2020). Although banteng hunting has reportedly ceased since 2015 due to customary regulations, hunting of other mammals persists.

Species data were obtained using a Bushnell Natureview HD camera trap. The camera was mounted 150 cm above ground, in front of two salt springs 30 cm apart, forming a 6.68 m² puddle. The site, though within dense forest, features an open area with grass and reeds. Soil analysis revealed a top layer of 83% sand, 8% clay, and 3% dust to 15 cm depth, underlain by gravel ("batu sopanan") and rock plates. The camera operated without bait from July 2017 to March 2018 (mainly wet season) and was checked monthly for maintenance and battery replacement.

Relative Abundance Index (RAI). Camera trap photos were processed using Picture Information Extractor to rename files, identify species, and determine independent events. Consecutive images of the same species within 30 minutes were treated as a single event (O'Brien *et al*. 2003). The number of independent photos per ungulate species was used to calculate the RAI (relative abundance per 100 trap days).

Temporal activity patterns and overlap. Camera trap timestamps were used to analyze daily activity patterns and temporal overlap among species. Data were processed in R using the 'overlap' package, which applies Kernel Density Estimation (KDE) to generate activity curves and calculate overlap coefficients (Meredith *et al*. 2017, Setiawan *et al*. 2016). Overlap values range from 0 (no overlap) to 1 (complete overlap), with values ≥0.7 considered significant. These analyses quantify how species share access to the mineral lick over a 24-hour period.

Co-occurrence patterns. Species relationships were assessed using the 'co-occur' package in R (Griffith *et al*. 2016). This probabilistic analysis identifies positive, negative, or random associations based on species co-occurrence frequencies (Veech 2013). Daily presence–absence data (1 = present, 0 = absent) were used as replicates.

A total of ten mammal species were recorded at the mineral lick over 282 survey days. Ungulates dominated, accounting for 1,430 out of 1,598 independent photographs (89.4%). Among 10 species photographed at the mineral lick sites, only four were ungulates (Fig. 2).

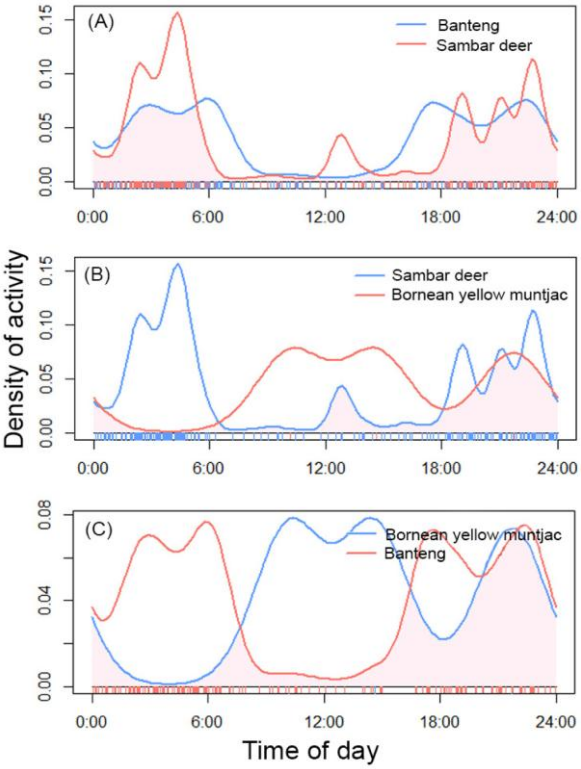

Figure 2. Temporal activity and overlap of three ungulates at a mineral lick: **(A)** Banteng-Sambar, **(B)** Sambar-Bornean yellow muntjac, **(C)** Banteng-Bornean yellow muntjac. Ungulate activity is represented as solid lines, and temporal overlap is represented as shaded areas.

Among these, two species showed the highest relative abundance: banteng, with 253.19 photos/100 active days, and sambar, with 251.42 photos/100 active days. The remaining ungulates and other mammals were recorded at much lower frequencies (Table 1). Banteng and sambar spend the longest time visiting the mineral lick, namely 14–15 hours in 24 hours. Bornean yellow muntjac (*Muntiacus atherodes*) spent a maximum of 3 h visiting the mineral lick in 24 hours, while the temporal activity patterns of the bearded pigs were not clear due to the small amount of data available.

Table1. Ungulate species in Mineral Lick; EN = endangered; VU = vulnerable; NT = near threatened; number of independent camera-trap records (N), Relative abundance index (RAI).

Family	Name	N	RAI
Bovidae	Banteng *Bos javanicus*^{EN}	71	253
Cervidae	Sambar *Rusa unicolor*^{VU}	709	251.4
Cervidae	Bornean yellow muntjac *Muntiacus atherodes*^{NT}	5	1.8
Suidae	Bearded pig *Sus barbatus*^{VU}	2	0.71

The density of visiting banteng increases from 17.00 to 08.00 h (nocturnal), with two peak periods (periods with the highest number of visits recorded in the 100 days) at 01.00 and 06.00 h. Sambar show more activity during the night (16.00–06.00 h) but with a peak visitation at 04.00 h. For Bornean yellow muntjac, the density of visiting activity is at 09.00–12.00 h (diurnal), with a peak of visits at 11.00 h. The degree of overlap between banteng and sambar is the highest (Δ_1=0.689). Meanwhile, banteng and Bornean yellow muntjac (Δ_1=0.41); sambar and Bornean yellow muntjac (Δ_1=0.35) have a lower degree of overlap (Fig. 3).

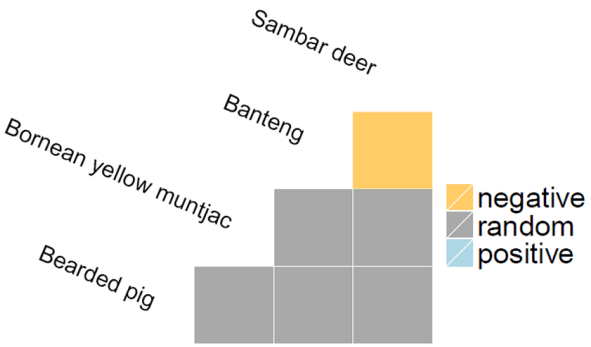

Figure 3. Heat map showing positive and negative species associations determined by a probabilistic co-occurrence model for ungulates. Species names are positioned to indicate columns and rows representing their pairwise relationships with other species.

The results of the probabilistic analysis show mostly random patterns of occurrence among ungulates based on their daily visits. From the heat map of ungulates, there is a negative association between banteng and sambar, and there is no positive association for ungulates in the mineral lick area.

This study shows that various ungulate species frequently visit mineral licks, though their visitation rates vary. Herbivore-frugivores like banteng, sambar, and yellow muntjac visit more often than omnivores such as bearded pigs, which rely less on licks due to a broader diet (Matsubayashi *et al*. 2007, Payne & Davies 1987). Mineral licks are especially important in Kalimantan forests, where the distributions of large mammals correlate more with mineral availability than forest type (Matsuda *et al*. 2015). Herbivores seek sodium, often deficient in tropical vegetation, prompting regular lick visits (Chong *et al*. 2005, Klaus & Schmidt 1998). Their primary food plants, rich in potassium, have diuretic effects, increasing sodium loss. Mineral licks in Belantikan Hulu contain significantly higher levels of sodium (500 mg/kg) and calcium (900 mg/kg) than nearby soils (Wicaksono *et al*. 2022), making them critical mineral sources.

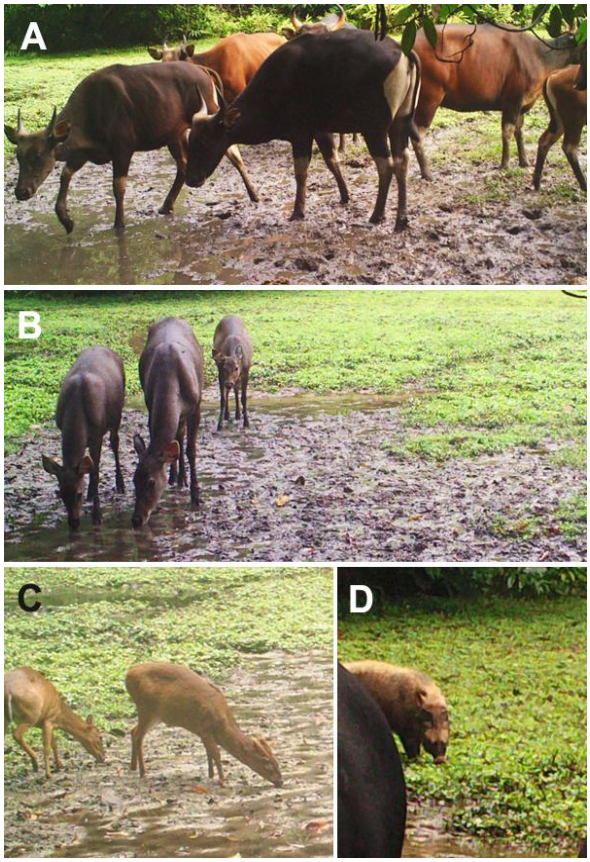

Figure 4. Ungulates were recorded by camera trap at the Penggaraman mineral lick; **(A)** Banteng, **(B)** sambar, **(C)** Bornean yellow muntjak, and **(D)** bearded pig.

Banteng and deer showed high temporal overlap in mineral lick visits, likely due to shared nocturnal habits. In contrast, muntjac, being diurnal, had lower overlap—possibly as an avoidance strategy (Tan *et al*. 2018). Co-occurrence analysis showed a negative

association between banteng and deer, with most visits occurring on different days, suggesting temporal partitioning to reduce direct competition. Camera trap images captured interference between the two species, indicating no clear dominance (Fig. 4).

Despite covering only 0.35 ha in the 200,000 ha Belantikan Forest, mineral licks serve as key activity hubs, increasing the potential for competition. While this study focused on temporal patterns, spatial segregation also likely plays a role in species coexistence (Tobler *et al*. 2009, Zanni *et al*. 2021). One limitation is the use of a single camera, which restricts observation of pre-entry behaviour or avoidance. Future studies should deploy multiple cameras from the edge to the centre of the lick to better understand species interactions. Additionally, factors such as predator presence and human disturbance may influence ungulate activity patterns. For example, human activity has been shown to alter mammal behaviour and reduce mineral lick use (Gray & Phan 2011, Blake *et al*. 2013, Laundré *et al*. 2010, He *et al*. 2022).

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