Short Note

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Where do the langurs criss-cross? Spatial understanding of group composition and habitat of mixed-species groups of Nilgiri langur (*Semnopithecus johnii* Fischer, 1829) and tufted gray langur (*Semnopithecus priam* Blyth, 1844) across the Western Ghats, India

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Abstract: An overlap of ranges of Nilgiri langurs (*Semnopithecus johnii* Fischer, 1829) and tufted gray langurs (*Semnopithecus priam* Blyth, 1844) in the Western Ghats resulted in the formation of mixed-species groups (MSGs) with a notable presence of brown morphs and significant changes in group composition and population dynamics. Our study investigated the composition of MSGs and examine the vegetation in their ranges across the Western Ghats. We identified three new locations with MSGs in the Nilgiris and southern Western Ghats predominantly found in deciduous forests (~50 %), at an average altitude of 621.01 m asl. The mean group size of MSGs was 10.9 ± 4.49_{SD} The geographic variation in the abundance of Nilgiri and tufted gray langurs, driven by their ecological adaptability and dispersal patterns, provides important insights into their ecological niches in the Western Ghats.

Keywords: population dynamics; mixed-species associations; interspecific groups; hybridization; sympatricity

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Ecological attributes at the landscape level influence the overlapping ranges of two species, often leading to the formation of mixed-species groups (MSGs). These overlapping ranges are a result of the cost and benefits of species finding specialised food in their shared habitats (Chapman and Chapman 2000). In such environments, interspecific competition, adaptation, and social interaction play major evolutionary roles, leading to the emergence of possible speciation pathways (Fooden 1982; Groves 1993; Pianka 1974). Continuous social interactions can drive this speciation and lead to the formation of genetically discontinuous groups through random genetic drift (Coyne 1992). Thus, the significance of these overlapping ranges of closely related species becomes very important from ecological, social, and genetic aspects.

Inter-group interactions occur at overlapping home ranges of non-human primates in tropical rainforests (Beaudrot et al. 2013; Haugaasen and Peres 2008), with some dispersal factors playing a role (Beaudrot and Marshall 2011). For instance, Nilgiri langurs (*Semnopithecus johnii*) and tufted gray langurs (*Semnopithecus priam*, commonly called Hanuman langurs) share several potential overlapping ranges in certain areas of the Western Ghats, India (Kumara et al. 2024). This overlap can occur naturally or as a consequence of anthropogenic disturbances and habitat alterations such as deforestation and fragmentation. Such overlap may result in ecological segregation; however, increased interaction leads to MSGs culminating in interbreeding and hybridization (Al-Razi et al. 2023; Choudhury 2008; Lhota et al. 2022; Lu et al. 2021).

Ecological factors influence the group composition and social structure of gray langurs. Sugiyama (1964) documented the social structure of one-male groups and instances of infanticide in Hanuman langurs which could be due to high population densities. However, Hrdy (1975) observed infanticide even in groups with low population density and proposed that infanticide is not a social pathology happening due to crowding but it is rather a male reproductive strategy. The population density of langurs in response to changes in environmental pressures and resource availability, affects their reproductive strategies and group cohesion (Mohnot et al. 1981; Rajpurohit et al. 2006). Conversely, Nilgiri langurs are found in evergreen rain forests as well as in rain shadow forests on the eastern slopes of the southern Western Ghats, where they share habitats with gray langurs (Kumara and Singh 2004; Singh et al. 1997a,b; Singh et al. 2016). Despite some ecological differences in feeding habits, where Nilgiri langurs are more folivorous than gray langurs (Kavana et al. 2015), these two species share similarities in their social structure (Poirier 1969; Tanaka 1965).

In the Western Ghats, Hohmann (1988) and Nag (2020) reported the presence of MSGs of Nilgiri langurs and tufted gray langurs. Kumara et al. (2024) predicted the potential range of MSGs in the fragmented landscape of the Western Ghats. Mahato et al. (2024) showed the variation in the morphotypes of individuals (coat colours ranging from dark gray to brown to dark brown morphs) in the MSGs along the altitudinal gradient in the Anamalai hills, as well as larger group size and multi-male–multi-female compared to Nilgiri and tufted gray langurs. However, not much information is available about the spatial distribution and social structure of MSGs of these two langur species in the overlapping ranges across the Western Ghats.

Based on the predicted potential distribution range of MSGs in the Western Ghats (Kumara et al. 2024), we identified the areas for further exploration to locate the MSGs and record their group composition. At those selected sites, field visits were made and we walked the existing trails. On detection of MSG group, we recorded the geocoordinates of the group location, altitude of the location, vegetation type, group size and group composition with morphotypes. Using the group size and composition data, we calculated the mean group size and age-sex ratios. We used the vegetation layer of the Western Ghats created by Ramesh et al. (1997, 2002) and reclassified it as shola grassland, evergreen forest, moist deciduous forest, dry deciduous forest, plantation, human habitation, and water bodies. We overlaid the geocoordinates of the MSGs, created a buffer of one km, and extracted the vegetation types using QGIS (version 3.28.3) software.

The study reports 18 MSGs from the four previously known locations and three new locations (Figure 1), including Gudalur, Vazhikkadavu, Silent Valley, Manjur-Mulli Road, Walayar, Anamalai Tiger Reserve (ATR), and Kalakkad-Mundanthurai Tiger Reserve (KMTR). The habitat of MSG was in the deciduous forests (47 %) and evergreen forests (19 %) (Table 1). They were observed at an average altitude of 621.01 m above sea level (asl).

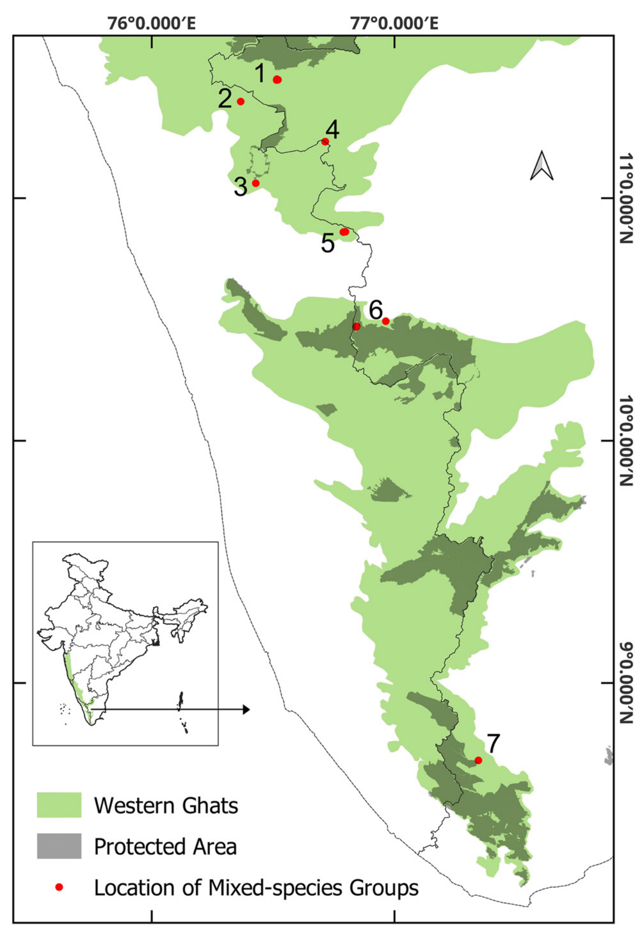


Figure 1: Map illustrating the locations of seven mixed-species group populations (1. Godalur, 2. Vazhikkadavu, 3. Silent valley, 4. Manjur-Mulli road, 5. Walayar, 6. Anamalai Tiger Reserve, and 7. Kalakkad-Mundanthurai) of Nilgiri langurs and tufted gray langurs recorded across the Western Ghats.

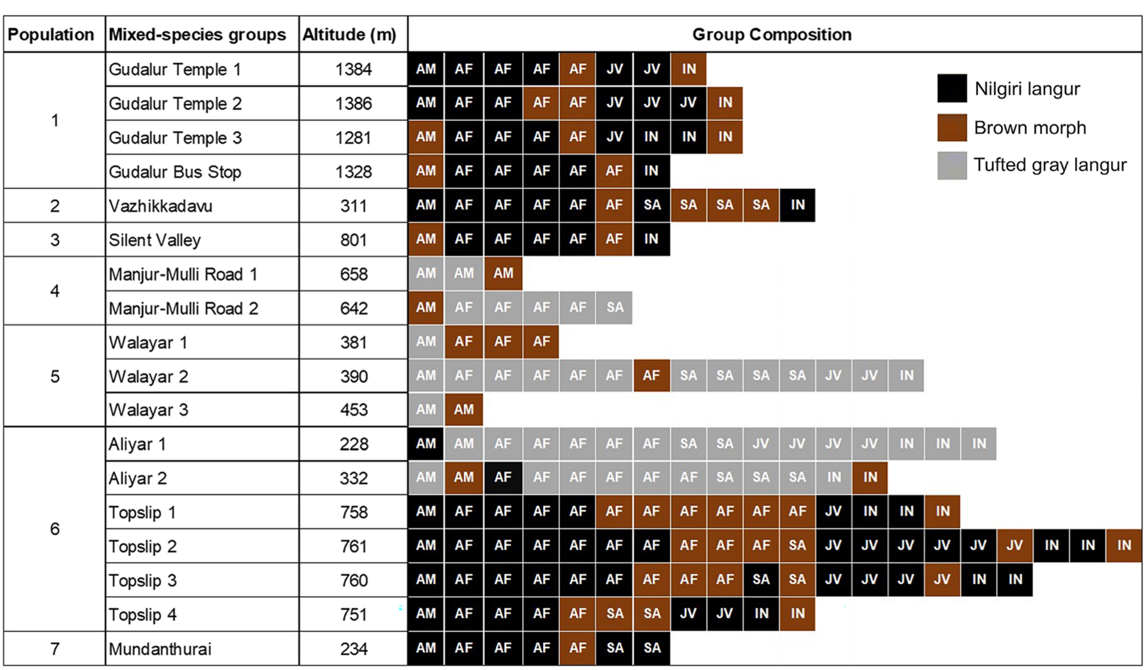
Table 1: Habitat characteristics of seven areas with mixed-species groups of Nilgiri langur and tufted gray langur in the Western Ghats.

Places	Kalakkad-Mundanthurai TR	Vazhikkadavu	Walayar	Manjur-Mulli Road	Anamalai TR	Silent Valley	Gudalur	Average
Altitude (m)	234	311	408	650	598.33	801	1,344.75	621.01
Vegetation types (%)								
Grassland	0.00	0.00	0.00	0.23	0.00	0.51	0.09	0.12
Evergreen forest	0.00	0.31	0.00	0.00	0.44	0.06	0.52	0.19
Moist deciduous forest	0.00	0.00	0.45	0.00	0.30	0.43	0.00	0.17
Dry deciduous forest	0.61	0.00	0.55	0.68	0.25	0.00	0.00	0.30
Forest plantation	0.39	0.69	0.00	0.00	0.00	0.00	0.09	0.17
Commercial plantation	0.00	0.00	0.00	0.09	0.00	0.00	0.31	0.06
Non-forest	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00

MSGs above ~750 m had no tufted gray langur but had different morphotypes (Figure 2); however, MSGs at lower altitudes had many Nilgiri langur individuals even up to 311 m at Vazhikkadavu and 234 m at KMTR. We observed a Nilgiri langur male associating with a tufted langur group at an elevation of 228 m near Aliyar in the Anamalai hills.

The average proportion of brown morphs found in 18 MSGs was 29.95 %. It was nearly the same in the case of MSGs dominated by tufted gray langurs (28.69 %) and Nilgiri langurs (30.75 %) (Figure 2). The mean group size of MSGs was 10.9 ± 4.49_{SD} individuals. The MSGs had 2.44 ± 1.59_{SD} males, 5.44 ± 1.97_{SD} females, and 3.06 ± 2.64_{SD} immatures in the group. The adult male ratio of Nilgiri langurs to tufted gray langurs was 1:0.78, whereas 1:0.45 for females and 1:0.38 for immatures.

The geographic variation in the abundance of these two langur species near their MSGs provides insight into the ecological niches in the Western Ghats. The distribution ranges of MSGs were characterized mostly by deciduous forests which could play a role as potential sites for intermixing between the two species. Although MSGs were sighted at different regions of



AM = adult male; AF = adult female; SA = subadult male; JV = juvenile male/female; IN = infant

Figure 2: Group compositions of 18 mixed-species groups of Nilgiri langur and tufted gray langur from seven populations (depicted in Figure 1).

ATR (Kumara et al. 2024; Nag 2020), but have not been systematically reported. The recent systematic documentation shows MSGs are found between 300 m and 800 m asl having domination of Nilgiri langur in higher altitudes and tufted gray langur at lower altitudes (Mahato et al. 2024). However, Nilgiri langur shows a wider distributional range along lower altitudes (Kumara et al. 2024), as recorded in the current study. This indicates the broader ecological adaptability and dispersal of the Nilgiri langur.

The average proportion of brown morphs in the large MSG populations in Topslip was 33.09 % (Mahato et al. 2024), which is consistent with the findings of the current study (29.95 %). Further, the mean group size of MSGs (10.9) in this study is close to the mean group size of Nilgiri langurs (9.1: Kumara et al. 2024) but less than the mean group size of MSG populations in Topslip (15.5: Mahato et al. 2024). Further, there are large group sizes of tufted gray langurs in dry deciduous forests (11.17: Mahato et al. 2024) or Nilgiri langurs in dry teak-mixed forests (12.19: Kumara et al. 2024). This may be due to a small sample size in each location or influenced by habitat structure and the availability of food resources (Chapman and Pavelka 2005; Chivers 1980; Kumar and Solanki 2008). Age-sex ratios revealed that Nilgiri langur individuals have greater representation in all age-sex classes, which may have an influence on social cohesion and group dynamics as a species-specific that requires further study.

Similar ecological niches and dispersal ability for closely related species lead to interspecific interactions and the formation of MSGs, and further might lead to interbreeding and hybrid formation, as documented in various taxons including colobines such as *Colobus* spp., *Piliocolobus* spp. and *Cercopithecus* spp. in Africa (Cords 1987; De Jong and Butynski 2010; Detwiler 2002; Gautier-Hion 1988; Groves 2007), *Semnopithecus* spp. and *Trachypithecus* spp. in Asia (Al-Razi et al. 2023; Choudhury 2008; Lhota et al. 2022; Lu et al. 2021; Nag 2020). The biological species concept defines species as "groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups" (Mayr 1940), but chances of interbreeding between sympatric species were reported (Groves 2012). It is crucial to understand whether this association leads to such interbreeding and hybridization, which could drive speciation or result in local extinction.

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