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Interactions of lion-tailed macaque (*Macaca silenus*) with non-primates in the Western Ghats, India

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Primates and non-primates inhabiting tropical forests may interact with each other since they coexist in the same communities. Primates usually interact with their prey, predators, competitors and neutral species. Using ‘all occurrence’ sampling, we have studied inter-specific interactions of lion-tailed macaques with non-primate species found in their habitat. We observed that the percentage of total time spent on interactions with non-primates was less than 1. Also, the percentage of total time spent in interacting with competitors, predators and neutral species was less than 0.5. The lack of predation pressure and lack of opportunities for mixed-species associations for increasing foraging efficiency appear to be the major reasons for the absence of interactions with non-primates. By comparing with studies from other primate habitat regions, we observed that primates in South Asia interact much lesser with non-primates than those in South America and Africa. A previous study showed that the interactions of lion-tailed macaques even with other primate species in the Western Ghats are less than expected by chance.

Keywords: Inter-specific competition, mixed-species troops, *Macaca silenus*, primate–predator interaction.

PRIMATES in tropical forests may interact with other non-primate species which coexist with them^{1–3}. These interactions could be either positive, negative or neutral^{4,5}, and may vary with space and time^{5–7}, largely depending on ecological and historical factors which shape them. The primates mainly interact with their prey, predators, feeding competitors and neutral species, and may display a variety of behaviours towards an interacting species⁵. Most direct interactions such as aggression and submission occur when two species encounter in close proximity⁸. Long-distance interactions such as alarm calls and spacing calls are important for communication about detection of predators and foraging⁹.

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The primate–non-primate interactions are more common in the neotropics, followed by Africa and Asia³. The primate–non-primate interactions are mainly with other mammals and birds, and usually the non-primates are attracted to the primates than the other way around³. It is stipulated that the chances of such commensal interactions are high in Asia, Africa and the neotropics, as primates in these regions are mainly large/medium-bodied, wasteful feeders with large group sizes inhabiting open habitats³. However, it has been observed that both body size and group size do not have any effect on primate–non-primate interactions³. The nature of primate interactions could be largely determined by species-specific temperament and personality^{5,10,11}.

Some interactions after encounters may result in active associations between interacting species which are formed more commonly for reducing predation pressure and increasing foraging efficiency^{1,6,12}. Generally, two species are defined to be in an association when they are in close proximity, usually within a distance of 50 m, and this may vary with the species being studied and their habitats¹³. Information flow between species that share common resources and predators is an important aspect of communities⁹. Such associations have been largely observed among primate–non-primate species as in the case of Hanuman langur (*Semnopithecus entellus*) – chital (*Axis axis*)¹⁴ and chacma baboon (*Papio ursinus*) – rock kestrel (*Falco rupicolus*) associations⁷. Also, the animals are often observed to interact when feeding on clumped resources and when their travel routes converge¹⁵.

Lion-tailed macaques are habitat specialists of tropical rainforests of the Western Ghats, India^{16–18}. Previous studies have shown that lion-tailed macaques avoid interacting with other primate species in the Western Ghats^{11,19}. Also, the studies assessing the inter-specific interactions of primates with non-primates in South Asia are rare in the literature. However, such studies are essential to understand community ecology and interdependencies of species in an ecosystem. Hence, we studied inter-specific interactions of lion-tailed macaques with other non-primates to understand whether primates in the Western Ghats interact with other species. Based on previous studies conducted on inter-specific interactions of other primates in Asia and primate–primate interactions in the Western Ghats^{11,13,20}, we expected the lion-tailed macaque to spend less time on inter-specific interactions with other non-primates in the Western Ghats. As lion-tailed macaques are found both in highly fragmented forests with largely open canopies and human disturbance as well as relatively undisturbed and large stretches of continuous forests²¹, we also intended to compare such inter-specific interactions between groups inhabiting both habitat types.

Our study conformed to the ethical guidelines for animal treatment of the University of Mysore, and we obtained permissions for conducting wildlife research from the Forest Departments of Kerala and Tamil Nadu.

We conducted the study in two sites in the Western Ghats: Nelliampathy and Valparai. In Valparai, data were collected from two different locations: Andiparai and Puthuthottam. Details about the study groups in Nelliampathy and Andiparai are given in Erinjery *et al.*¹¹. The group in Nelliampathy inhabited a contiguous forest surrounded by coffee/tea gardens and the groups in Andiparai and Puthuthottam inhabited fragmented forest patches. Puthuthottam is a privately owned rainforest fragment of about 1.25 km² area surrounded by tea gardens, at an altitude of about 1100 m. Since both these are fragmented habitats, we combined the data of these locations for the present study.

The study in Nelliampathy was conducted from December 2010 to October 2012 with 736 h of total observation time. The study in Valparai was conducted from September 1996 to August 1997 with 1696 h of total observation time. We systematically followed the macaques for 92 and 212 d in Nelliampathy and Valparai respectively (8 h/day), and used only these data for the analysis. The data were collected between 0800 and 1600 h for full day.

We employed ‘all occurrences’ sampling method by taking detailed notes of interactions, as and when they occurred. We collected data on date, time, interacting species, activity of macaque and other species during the interaction, type of interaction, aggressor and the recipient, displacement (if any), species displaced, and duration of the interaction. For analysis, we considered only those interactions wherein we could observe the beginning and end of an interaction.

We divided inter-specific interactions into two types: long-distance interactions and close-proximity interactions. We included alarm calls as a long-distance interaction. We considered an arboreal species to be involved in a close-proximity interaction only if that species was within a proximity of 5 m from an individual of the lion-tailed macaque group. For terrestrial animals, we considered an interaction to take place only when the animals were directly under the trees where lion-tailed macaques were present. We considered the lion-tailed macaque to interact with a predator, which was mostly a raptor, only when the latter directly hovered over the trees where lion-tailed macaques were present. We further divided the close-proximity interactions into two types: neutral and non-neutral. In neutral interactions, lion-tailed macaques tolerated the other species. In non-neutral interactions, they were aggressive towards other species. Aggressive interactions included chasing, fighting and/or displacing of interacting species. When interacting with predators, we considered lion-tailed macaques to be aggressive if they gave continuous threatening bark calls directed at the predator. We did not observe any interactions where lion-tailed macaques were submissive to other species.

On the basis of previous studies on lion-tailed macaques and our own long-term observations in the

Table 1. Frequency, mean duration, percentage of total frequency and percentage of total time spent on inter-specific interactions by lion-tailed macaques with non-primates in Nelliampathy and Valparai

Location	Species interacting	Frequency of interaction	Mean duration of an interaction (min)	Percentage of total frequency of interaction	Percentage of total time spent on interaction
Nelliampathy	DHL*	2	7.5	3.8	3.7
	SE, MHE*	6	11.6	11.3	17.3
	GS*	24	6.3	45.3	37
	GIH*	6	5.0	11.3	7.4
	RTD*	14	9.6	26.4	33.3
	SBR*	1	5.0	1.9	1.2
	Total	53	7.6	100	100
Valparai	DHL	2	5.0	2.6	1.0
	SE	18	11.7	23.4	21.8
	LEO*	1	30.0	1.3	3.1
	GS	34	17.9	44.2	44.6
	GIH	3	16.7	3.9	5.2
	BD*	7	17.9	9.1	13.0
	RTD	8	9.8	10.4	8.1
	SBR	3	5.0	3.9	1.6
	ELE*	1	15	1.3	1.6
	Total	77	12.51	100	100

*GS, Indian giant squirrel; DHL, Dhole; SE, Crested-serpent eagle; MHE, Mountain hawk-eagle (only one killing episode); RTD, Racket tailed drongo; SBR, Sambar; GIH, Great Indian hornbill; BD, Barking deer; LEO, Leopard; ELE, Elephant.

**Figure 1.** A mountain hawk-eagle with a lion-tailed macaque infant as prey.

field, we categorized the results of interactions as follows: interactions with predators, interactions with competitors and interactions with commensal/mutualistic species. The major predators of lion-tailed macaques were leopard (*Panthera pardus*), crested serpent eagle (*Spilornis cheela*) and changeable hawk-eagle (*Nisaetus cirrhatus*)^{22,23}. However, we also included other species which elicited threat calls and alarm calls from lion-tailed macaques. The species which shared similar food resources with lion-tailed macaques were considered as

competitors. We considered Indian giant squirrel (*Ratufa indica*) and great Indian hornbill (*Buceros bicornis*) as competitors, since they shared the same fruits that the macaques consumed. If the other species benefitted from the interaction with lion-tailed macaques, we considered it as commensal and if both species benefitted, we considered it a mutualistic interaction.

We used chi-square test of proportions to compare between interactions from different study sites. The alpha level was kept at 0.05 and we performed all tests using SPSS 20.

Lion-tailed macaques spent 0.92% and 0.95% of their time in interacting with non-primates in Nelliampathy and Valparai respectively, with no difference in the duration of interactions across study sites (chi-square test of proportions: $\chi^2 = 0.051$, $P = 0.48$). The frequency of interactions was 0.05 interactions/h in Valparai and 0.07 interactions/h in Nelliampathy (Table 1).

The interactions with non-primate species included 0.19% and 0.26% of their time with potential predators in Nelliampathy and Anamalai respectively, with no difference across sites (chi-square test of proportions: $\chi^2 = 0.051$, $P = 0.17$). Out of the total time spent on interactions, lion-tailed macaques interacted with their predators 21% and 27.5% of their time in Nelliampathy and Valparai respectively (Table 1). We observed two killing episodes by the predator (a lion-tailed macaque infant caught by crested serpent eagle and the other by mountain hawk-eagle, *Nisaetus nipalensis*) during the whole study period. The observation of mountain hawk-eagle capturing lion-tailed macaque infant is the first case of such predation in the wild (Figure 1). The crested

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Table 2. Frequency and mean time spent on neutral and non-neutral interactions by lion-tailed macaques (LTMs) with non-primates in Nelliampathy and Valparai. Values in parenthesis are the mean time spent on each interaction

Interaction	Nelliampathy				Valparai			
	Observation time (h)	Type of interaction			Observation time (h)	Type of interaction		
		Frequency (mean time spent (min)/interaction)				Frequency {mean time spent (min)/interaction}		
		Aggressive	Tolerant	Submissive		Aggressive	Tolerant	Submissive
LTM and DHL	736	2 (7.5)	0 (0)	0 (0)	1696	2 (5)	0 (0)	0 (0)
LTM and SE, MHE	736	6 (11.6)	0 (0)	0 (0)	1696	18 (11.7)	0 (0)	0 (0)
LTM and LEO	736	0 (0)	0 (0)	0 (0)	1696	1 (30)	0 (0)	0 (0)
LTM and GS	736	11 (8.63)	13 (9.6)	0 (0)	1696	4 (7.5)	30 (13.3)	0 (0)
LTM and GIH	736	1 (5)	5 (6)	0 (0)	1696	1 (15)	2 (15)	0 (0)
LTM and RTD	736	4 (5)	10 (11.5)	0 (0)	1696	2 (5)	6 (11.4)	0 (0)
LTM and SBR	736	0 (0)	1 (5)	0 (0)	1696	0 (0)	3 (5)	0 (0)
LTM and BD	736	0 (0)	0 (0)	0 (0)	1696	0 (0)	7 (17.9)	0 (0)
LTM and ELE	736	0 (0)	0 (0)	0 (0)	1696	0 (0)	1 (15)	0 (0)

serpent eagle was a common predator for primates. They continuously circled around and swooped down when presented with an opportunity. The lion-tailed macaques gave repeated alarm calls at the sight of crested serpent eagle and mountain hawk-eagle ($N=24$). Twenty out of 23 interactions with crested serpent eagles took place during the months (June–August) when the macaques had young infants. There were four instances of interactions with dholes (*Cuon alpinus*), and lion-tailed macaques made barking/threatening calls at the sight of dholes. The lion-tailed macaques also made barking calls in the presence of Asian elephants (*Elephas maximus*; $N=1$) and leopard ($N=1$).

The most frequent non-primate interaction of lion-tailed macaques was with the Indian giant squirrel ($N=58$). The macaques spent 0.43% (0.03 interactions/h) and 0.41% (0.02 interactions/h) time interacting with squirrels in Nelliampathy and Valparai respectively. Out of the total time spent on interactions, lion-tailed macaques spent 44.6% and 37% of their time interacting with Indian giant squirrel alone in Valparai and Nelliampathy respectively. Table 2 presents the data on the type of interactions of lion-tailed macaques with the other species. The lion-tailed macaques were more frequently neutral ($N=43$) than aggressive towards Indian giant squirrel ($N=15$). Most aggressive interactions (93%) occurred when the two species were feeding. Lion-tailed macaques and other primates in the study area, Nilgiri langurs (*Semnopithecus johnii*) and bonnet macaques (*Macaca radiata*) became alert whenever Indian giant squirrels gave alarm calls. Only two out of nine interactions with the great Indian hornbill included aggression. All these interactions occurred on *Ficus* trees, where both were seen feeding together on figs.

Macaques spent 0.30% (0.02 interactions/h) and 0.17% (0.01 interactions/h) of their time interacting with racket-tailed drongos (*Dicrurus paradiseus*) in Nelliampathy

and Valparai respectively. These interactions took place mainly when the macaques were foraging/feeding for insects ($N=22$). The drongos continuously followed the macaques and fed along with them. In 6 out of 22 interactions, the macaques chased the drongos. All interactions were commensal. Macaques spent 0.01% (<0.01 interactions/h) and 0.03% (<0.01 interactions/h) time interacting with sambar (*Rusa unicolor*) in Nelliampathy and Valparai respectively. Both were found to feed together on jackfruit (*Artocarpus heterophyllus*) during monsoon ($N=4$). The macaques reacted with alertness to the alarm calls given by the sambar in three observations. Barking deer (*Muntiacus muntjak*) were observed to feed on jackfruit dropped by lion-tailed macaques ($N=5$), and the macaques reacted with alertness to the alarm calls by barking deer ($N=4$). The interactions with barking deer were only seen in Valparai (0.28%; 0.01 interactions/h).

The interdependencies of species in a community are important to understand the community ecology of a species. While several researchers have studied polyspecific associations and interactions between primate species, studies describing the non-primate interactions in South Asia are rare in the primate literature. In the present study, we collected data on non-primate inter-specific interactions of an endangered primate, the lion-tailed macaque, inhabiting the Western Ghats of South India, to assess their interdependency with non-primates. We found that the interaction of lion-tailed macaques with non-primates was $<1\%$ of the total observation time. This shows that the lion-tailed macaque hardly interacts with any non-primate in its habitat. These results are similar to the primate–primate interactions in the Western Ghats¹¹.

Haugaasen and Peres¹ showed that interactions between primates and other mammals are rare in central Amazonian forests. However, a meta-analysis from different regions has shown that primate–non-primate interactions are most common in the neotropics, followed by

Africa and Asia³. It has been observed that the interactions between primates and other species in Africa, Southeast Asia and Central America are higher compared to the present study^{1,7,24–28}. The absence of large raptors that predate on adult primates may be the major reason for absence of associations or interactions between primates and non-primates in South Asia²⁹.

Primates mainly form associations after encounters with other non-primates for increasing foraging efficiency or decreasing predation pressure^{3,29}. The present study has shown that the predation pressure for lion-tailed macaques is less in the Western Ghats (<0.50% of the total observation time), and they do not associate with other non-primates for increasing foraging efficiency. It has been observed that the lion-tailed macaques are aggressive towards Indian giant squirrel in most of the interactions during co-feeding. This is probably because of competition between these species, which feed on fruits of the same trees. The lion-tailed macaque has even been observed to predate on the Indian giant squirrel, Indian giant flying squirrel (*Petaurista philippensis*), three-striped squirrel (*Funambulus palmarum*), frogs, lizards and bats^{16,30–32}. One instance of lion-tailed macaque unsuccessfully attacking a mouse deer (*Moschiola indica*) fawn is also reported³⁰. However, it has been found that other mammals and birds, including racket-tailed drongo, barking deer and sambar were associated with lion-tailed macaques to increase their foraging efficiency by feeding on the food dropped by the macaques. Also, lion-tailed macaques were observed to be alert to alarm calls of barking deer, sambar and Indian giant squirrel. Hence, while interactions with racket-tailed drongos were commensal, those with barking deer and sambar were mutualistic. Additionally, we observed the Puthuthottam lion-tailed macaque group to interact with humans frequently.

The lack of inter-specific interactions in different habitats of lion-tailed macaques indicates that the community composition of higher vertebrates in the Western Ghats might not be largely influenced by interdependencies between species, but due to the anthropogenic and historical factors in the past. Also, the low percentage of time observed for associating and interacting shows that lion-tailed macaques inhabiting the Western Ghats do not form active associations with other vertebrates, with only chance interactions due to sharing of similar habitats with other species. However, the frequency of interactions may depend on the density and abundance of non-primates in a particular study site. Also, the present study shows that there is little difference in interactions between lion-tailed macaques inhabiting contiguous and fragmented forests.

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Interactive systems regarding global software development and offshoring

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Modern information technology (IT) methods are re-shaping the global market with great success. With today’s global software industry, IT has made innovations everywhere, including businesses and consumer practices. This has made developing countries like

India and China participate in the global market. This communication focuses on intelligent interacting systems which are present over globe and these are a source of rising the software development cycle with the help of modern communication facilities. Free e-Market globalization is now vital for billions of people. However, IT leadership is not possible without a review of the existing system. The present study is based over the issue of the global market related research, education and investment in IT technology. IT-based-leadership can give sustainable global competitive advantage to our country. So the role of iterative software development is crucial to be targeted in a systematic fashion.

Keywords: Global software development, information technology, innovation, software services, technology.

THE developing countries are adopting incremental export-oriented software development. These services and trends of the industry are the basis for talent and quality of work, and have also brought more investment. Europe and America are high-wage countries for software and services; they are now increasingly looking for cheap labour, thus resulting in offshoring. International trading of software services creates several jobs. Services trade in software development provides more skilled workers to firms of developing countries. This aspect leads the policy makers to target more opportunities and challenges to produce precious national income. This income and new employment opportunities are the real fruit of the global software development (GSD)¹⁻³. Multinational companies are doing business in countries with low wages for capital saving though local markets.

In the present study, we consider the following:

- (a) Software and information technology (IT) as a whole.
- (b) Programming and development.
- (c) Software testing of all types using the principles of GSD.
- (d) Remotely performing software maintenance work that is offshore.
- (e) On-line research and development, such as software architecture, product design, project management, etc.
- (f) IT consultation and on-line guidance of business strategy.
- (g) Physical product manufacturing like semiconductors, computer hardware, etc.
- (h) Business process outsourcing/services such as financial analysis, on-line accounting services, digital art, desktop publishing, high-end services, etc.
- (i) Call centres and telemarketing.

The software industry works across national borders more closely associated with all of the above categories.

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