

Ecology of Clouded Leopard

Neofelis nebulosa in an

East Himalayan Biodiversity Hotspot -

Carnivore Coexistence in

Manas National Park, Assam, India

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**Ecology of Clouded Leopard (*Neofelis nebulosa*)
in an East Himalayan Biodiversity Hotspot -
Carnivore Coexistence in
Manas National Park, Assam, India**

**Final Report
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SUMMARY

Sympatric species occupying similar niche can result in competitive exclusion of subordinate species. However, species are able to avoid interspecific competition through morphological, physiological, or behavioural trade-offs, which in turn leads to differences in resource use. A guild of wild species of Felidae comprising various combinations of up to eight species is distributed across South-east Asia, with species ranging in size from the tiger (*Panthera tigris*) to the flat-headed cat (*Prionailurus planiceps*). Little is known of the ecology of most of these species, and less of their guilds. Large felids such as tigers and leopards coexist in most of their ranges. The sympatric association of such large cats has been studied and debated in most tropical forests of India. The clouded leopard (*Neofelis nebulosa*), a potent ambassador species for conservation, is among the least known.

The clouded leopard is the smallest of the large felids and is least studied due to its secretive nature and nocturnal behaviour. The species is an umbrella species for the Asian forest ecosystem and can be found along the foothills of the Himalayas through Nepal, Bhutan, and India to South China down to Peninsular Malaysia, and on the islands of Sumatra and Borneo. The clouded leopard is vulnerable on the IUCN Red List of Threatened Species and faces a global decline in population and contraction in its geographic range. The species occupies areas undergoing some of the most rapid deforestations and is threatened by poaching and wildlife trafficking. Clouded leopards are apex predators in many Southeast Asian rainforests, although they co-occur with larger predators such as tigers, leopards, dholes; their density, activity, and habitat use may vary. Although there have been discoveries regarding the felid guilds and habitat use of the Sunda clouded leopard, and the threat to the species from habitat loss, little is known for the mainland clouded leopard and the felids with which it is sympatric.

Despite the fact that tropical rainforests are known for its high biodiversity and species richness, the scarcity and/or the cryptic behaviour of some of the species have resulted in the scarcity of

information about these species. The tendency of many rainforest species to avoid humans on existing tracks (where most transect surveys are done) is well known. These conventional methods include surveys on the footprints, dung, calls, live-trapping, den counts and direct observation. All these surveys are usually performed along transects, and in the past, they were the preferred method in various countries. However, walking along transects to observe terrestrial mammals in tropical rainforests can be extremely challenging. The observers' different abilities to detect and recognize the species may lead to a bias during data collection, increasing the likelihood of animals fleeing unobserved. Presence-absence survey using transects lines or logging tracks may not yield substantial evidence of species diversity. Thus, if any survey were to be conducted without considering these factors, most wildlife surveys could expect a biased trend.

In a dense tropical rainforest, camera-traps are useful to detect cryptic species, estimating species diversity, movement, interactions, habitat associations, abundances using individual recognition and, recently, without individual recognition in various countries. A good image from the camera trap is indisputable regarding a certain species' presence compared to an interview or conventional survey methods. The utilization of camera-traps has revealed the presence of secretive rainforest dwelling species, which have been overlooked by applying the traditional transect surveys. In India, this method has been used in estimating densities and abundances of various carnivore species in several protected areas, but few attempts have so far been made in the dense forests of tropical evergreen habitats of the north-eastern part. The use of camera trapping rate as an index of abundance is both promising and cost-effective for the rapid assessment of animal abundance in remote areas or where alternative methods are unfeasible.

The study was conducted in tropical semi-evergreen forests of Manas National Park (MNP), Assam, India. The objectives of the study were to (1) estimate the status of clouded leopard and other carnivores, (2) assess prey status and feeding ecology of clouded leopard, and (3) determine the factors governing coexistence of carnivores.





Objective 1

Methods: The present study was initiated from October 2016 to October 2019. Fieldwork was carried out during three sampling periods: April 2017-June 2017, December 2017-May 2018, and November 2018-May 2019. A preliminary survey was initiated with open and close-ended interviews with particularly the forest officials (n=75) to gather baseline information on clouded leopard sightings across all three ranges at a beat level. Based on the pre-survey results and sightings of clouded leopards, a total of 554 camera-traps were deployed in a grid-based approach (grid size: 1 km²) during three sampling periods covering an area of 270 km². Relative abundance index (RAI) of clouded leopard and other carnivores was calculated as a total number of independent photographs for each species divided by total trap nights and then multiplied by 100. Multiple photographs of single individuals within a 30-min period were recorded as one effective photograph. We identified clouded leopards by a distinctive cloud-like pelage pattern. Awareness, educational programs, and training workshops on clouded leopard ecology, threats, conservation issues, etc. were organized among school children, locals, drivers, forest staff, and tourist guides.

Results: Questionnaire surveys revealed that clouded leopards were reported in all three ranges over 13 years in the northern boundary of MNP (Doimary, Mathanguri, Kheroni & Latajhar). A total of 19 carnivores were recorded with 2673 independent records over the sampling period of 13,398 trap nights. RAI for the photo-captured species ranging from clouded leopard (0.15) to tiger (4.77) for large-medium carnivores and from Chinese ferret-badger (0.02) to small Indian civet (4.42) for small carnivores. Twelve individuals of clouded leopards were identified out of 21 camera-trapped photographs. To raise awareness about clouded leopard among locals, school children, tourist guides, and drivers, we distributed an information poster consisting of all the general information about the clouded leopard, its classification, distribution (with maps), habitat, biology, conservation status, threats, etc. Training workshops were conducted for forest staff addressing wildlife monitoring techniques and instruments.

Objective 2

Methods: We used photographic rates or RAI from camera-trapping as prey encounter rates to measure prey availability for clouded leopards and other carnivores. RAI of prey species was estimated the same as that calculated for carnivores. Different published literature from various sources was searched, and data on prey density in MNP were collected and used as secondary data. Diet spectrum of clouded leopards was summarised according to published studies conducted in MNP, if no information was available, studies in nearby Southeast Asian countries were used instead.

Results: A total of 21 prey species were recorded with 22,225 independent records over the whole sampling period of 13,398 trap nights. The RAI for the photo-captured prey species ranging from chital (0.02) to Asiatic elephant (77.32) for large prey, from Assamese macaque (0.03) to red junglefowl (11.24) for small prey, from Assamese macaque (0.03) to rhesus macaque (5.13) for arboreal prey and from chital (0.02) to sambar (41.81) for potential prey of clouded leopards. A total of four studies (2007-2009, 2012-2013, 2013, and 2014-2016) were conducted on prey density in MNP and mainly estimated large prey density. The detailed literature review suggested that clouded leopards consume a variety of species, including deer, pigs, primates, rodents, porcupines, pheasants, pangolins, squirrels, domestic animals, and sometimes fish and snakes. Rhesus macaque, barking deer, and Himalayan-crestless porcupine likely were the most important prey species of clouded leopards given their body size and high RAIs in MNP.

Objective 3

Methods: Capture histories were created for all the photo-captured species using daily capture events to determine the presence or absence of each species at each camera station. Using these capture histories, spatial interactions (positive, negative, or random) were investigated between sympatric carnivore species pairs using probabilistic models. The date and time printed on the photographs were used to describe the diel activity period of clouded leopard and other photo-captured species. The species were classified as diurnal, nocturnal, mostly diurnal, mostly nocturnal, crepuscular, or cathemeral. We also calculated the slopes of mean vector length in





relation to the body mass of mammals using bivariate reduced major axis (RMA) models on log-transformed data. The activity patterns for each species were described using the *kernel density estimation curves*. Overlap coefficients among the daily activity patterns of clouded leopards, sympatric carnivores, and their potential prey were estimated. The precision of this estimator was obtained through 95% confidence interval (CI), as percentile intervals from 999 bootstrap samples. Because the coefficient of overlap is purely descriptive, i.e., does not provide a threshold value below which two activity patterns might be significantly different, we used the Mardia Watson Wheeler (MWW) test. To study the effects of different moon phases on the temporal forest use patterns of mammals, moon phase was classified into new, waxing, waning, and full moon. *One-way ANOVA*, *Dunn-Sidak*, *bivariate* and *partial correlation* tests were conducted to measure the degree of association and pairwise comparisons among records of predator-prey as well as dominant-subdominant assemblages in each moon phase. We performed the lunar cycle transformation to a 360° scale to analyze mammalian activity data through circular statistics using circular-linear correlation. We provided the mean vector (μ) and the length of the mean vector (r). The Rao's spacing test (U) for uniformity around the circular space was used to assess whether mammals' activity was uniform across the lunar cycle.

Results: The spatial niche differentiation among the species in MNP is not a determining factor as no statistically significant spatial co-occurrence patterns were found between the species pairs except for the three pairs of large carnivores and nine pairs of small carnivores that were positively associated. Fifty-one percent of records were detected in the diurnal period, followed by 38% in the nocturnal phase and 11% during twilight. Small carnivores such as leopard cat and civets were strictly nocturnal, whereas yellow-throated marten and mongooses were diurnal. Medium-sized carnivores were either nocturnal (clouded leopard) or diurnal (dhole), whereas large carnivores (tiger, leopard, Asiatic black bear) were cathemeral. A significant negative relationship was observed between mean vector length and log-transformed body mass for mammals ($r^2=0.61$, $P<0.001$; slope= $-0.17 \pm SD 0.03$; intercept= $0.69 \pm SD 0.05$). A high degree of temporal overlap (>0.75) was found between most sympatric carnivores with distinct activity peaks, while a low overlap (<0.50) was observed between different body-sized carnivores. The

leopard showed high temporal overlap with large-sized prey, whereas dhole and clouded leopard had a high overlap with medium-sized prey. The clouded leopard activity was predominantly nocturnal and followed a bimodal pattern with activity peaks at 21:00-23:00 h and 02:00-04:00 h. The temporal overlap of clouded leopards (>0.70) with tigers and leopards was relatively high. In the case of its prey, clouded leopards had maximum overlap with sambar [$\Delta_1=0.89$ (95% CI 0.68-0.92)] and Himalayan crestless porcupine (0.77). The activity of viverrids was negatively correlated ($r=-0.44$, $p<0.01$) with lunar cycles, perhaps to increase foraging efficiency or as an anti-predator strategy. Large prey ($\mu=133.23^\circ$) and small prey ($\mu=131.35^\circ$) activity were high during brighter nights due to better visual detection in detecting or avoiding predators. Dominant species activity was least affected by the lunar cycle among forest-dependent mammals, whereas subdominant species activity was either lunarphobic or lunarphilic.

Conclusion & Way Forward: In tropical semi-evergreen forests, camera-trap surveys tend to be more cost-efficient, both in terms of finance and human effort, than other survey methods, and provide very detailed ecological information on rare, elusive and shy species such as clouded leopard (*Neofelis nebulosa*). The study provides baseline information on density, abundance, prey species, and feeding ecology of clouded leopard in MNP, Assam, India. This study explored a broad description of the spatial and temporal ecology of large-small carnivores, including intraguild, predator-prey, and dominant-subdominant interactions. Such data can be used to study existing patterns in various ecological communities. Our study shows how potentially competing species overlap or avoid each other temporally. The study also provides first insights into the moonlight effects on the mammalian community in the forested habitats of Manas and shows how the activity of mammals is correlated with lunar phases. Our findings indicate that MNP supports a diversity of mammalian fauna of conservation concern. Continued monitoring of the existing populations of wildlife species and protracted support for conservation will be critical for the future ecological health of the park.

