**Secrets of the clouded leopard: abundance, habitat use and coexistence in tropical forest of Manas National Park, Assam, India**

Urjit Bhatt and Salvador Lyngdoh

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Supplementary Material 1 Format of a questionnaire survey conducted with the forest officials (n=75) to gather baseline information on clouded leopard sightings across all three ranges in Manas National Park.

Name: ………………………………………………… Age: ………. Gender: Male / Female Designation: …………………………………………………………………………………… Education status ……………………………. Salary………………………………………….. Range: ……………………………………… Beat: …………………………………………... Place: ………………………… Village: ……………………… District: ……………………. Latitude: ……………………………………. Longitude: ……………………………………..

1. How long have you been working in the forest department?

…………………………………...

1. Have you seen any carnivore while working with the forest department? If yes, which all?

……………………………………………………………………………………………….

1. Have you ever seen Clouded Leopard? Yes / No

If seen, what time period are you reporting about?

(1) 1981-1985 (2) 1986-1990 (3) 1991-1995 (4) 1996-2000 (5) 2001-2005 (6) 2006-2010 (7) 2011-2015 (8) 2016-2020

Exact Year: ……………………….

1. What kind of general area are you reporting about?

(1) Riverine Forest (2) Grassland Forest (3) Moist-mixed Deciduous Forest (4) Semi-evergreen Forest

1. Name of the Beat / Range of Clouded Leopard sighting: ……….…………………………..

If outside the PA, then Village name: ……………………………………………………….

1. How well did you know the place in the period mentioned above?

(1) I live here (2) I worked there (3) I studied there

1. How frequently did you see Clouded Leopard in the time period and locality / area chosen above?

(1) Never: I saw no Clouded Leopard (2) Occasionally: Several times in a month (3) Rarely: A few times in a year

1. Do you have the presence of clouded leopard cub in your area in the last 12 months?

Yes / No

If yes, mention the month of sighting

……………………………………………………………………………………………….

1. What is your view on clouded leopard population in your area?

(1) Increasing (2) Decreasing (3) Stable (4) No Idea

1. If decreasing, then what are the main reasons behind it?

(1) Depletion of prey species (2) Loss of habitat / Conversion of habitat (3) Poached and smuggled for the skin

Any other reason ……………………………………………………………………………

1. Have you ever come across any livestock lifting (e.g., goat, ducks, hen) by clouded leopard in the surrounding villages?

Yes / No

If yes, please mention village name and district …………………………………………….

1. Have you heard of any report of carnivore conflict with locals or forest staff? If yes, then mention details.

………………………………………………………………………………........................

1. Have you come across clouded leopard being sold in the market?

Yes / No

If yes, please mention name and the address of the market place

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14. Additional information if any.

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Supplementary Table 1 Independent records (n) and Relative Abundance Index (RAI) of photo-captured predator & prey species through camera-trapping in Manas National Park. RAI was calculated as independent records × 100 / trap nights. Estimated RAI for each species with associated standard errors were given in parenthesis. The mean average body mass of mammals was taken from Prater (1971), Menon (2003) and Karanth & Sunquist (1992). Potential prey species of clouded leopards are highlighted in red. Species with less than 10 encounters were removed from the analysis and are indicated with an asterisk (\*).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S. No. | Species | n | RAI | Mean Body Mass (kg) |
| Carnivore species |
| 1 | Tiger *Panthera tigris* | 466 | 4.09 (±0.33) | 218 |
| 2 | Leopard *Panthera pardus* | 452 | 3.97 (±0.34) | 59 |
| 3 | Asiatic black bear *Ursus thibetanus* | 28 | 0.25 (±0.04) | 102.5 |
| 4 | Dhole *Cuon alpinus* | 163 | 1.43 (±0.39) | 15 |
| 5 | Clouded leopard *Neofelis nebulosa* | 21 | 0.18 (±0.05) | 19 |
| 6 | Leopard cat *Prionailurus bengalensis* | 377 | 3.31 (±0.30) | 3.5 |
| 7 | Jungle cat *Felis chaus* \* | 5 | 0.04 (±0.02) | 5.5 |
| 8 | Large Indian civet *Viverra zibetha* | 309 | 2.71 (±0.38) | 7.5 |
| 9 | Small Indian civet *Viverricula indica* | 402 | 3.53 (±0.49) | 3.6 |
| 10 | Asian Palm civet *Paradoxurus hermaphroditus* | 221 | 1.94 (±0.20) | 3.5 |
| 11 | Crab-eating mongoose *Herpestes urva* | 133 | 1.17 (±0.18) | 0.75 |
| 12 | Small Indian mongoose *Herpestes auropunctatus* | 34 | 0.30 (±0.14) | 1.4 |
| 13 | Indian grey mongoose *Herpestes edwardsii* | 28 | 0.25 (±0.18) | 2.29 |
| 14 | Yellow-throated marten *Martes flavigula* | 17 | 0.15 (±0.05) | 1.8 |
| 15 | Chinese ferret badger *Melogale moschata* \* | 3 | 0.03 (±0.01) | 2 |
| 16 | Smooth-coated otter *Lutrogale perspicillata* | 10 | 0.09 (±0.06) | 8.9 |
| 17 | Chinese pangolin *Manis pentadactyla* \* | 2 | 0.02 (±0.01) | 4.5 |
| Prey species |
| 18 | Asiatic elephant *Elephas maximus* | 6386 | 56.08 (±6.29) | 2088 |
| 19 | One-horned rhinoceros *Rhinoceros unicornis* \* | 54 | 0.47 (±0.25) | 1900 |
| 20 | Gaur *Bos gaurus* | 3643 | 31.99 (±3.54) | 450 |
| 21 | Wild buffalo *Bubalus arnee* | 324 | 2.85 (±0.38) | 900 |
| 22 | Sambar *Rusa unicolor* | 4302 | 37.78 (±3.16) | 134 |
| 23 | Himalayan goral *Naemorhedus goral* \* | 1 | 0.01 (±0.01) | 38 |
| 24 | Chital *Axis axis* \* | 1 | 0.01 (±0.02) | 47 |
| 25 | Northern red muntjac *Muntiacus vaginalis* | 1523 | 13.37 (±1.27) | 21 |
| 26 | Hog deer *Axis porcinus* \* | 229 | 2.01 (±1.19) | 40 |
| 27 | Wild boar *Sus scrofa* | 2310 | 20.28 (±2.71) | 32 |
| 28 | Himalayan crestless porcupine *Hystrix brachyura* | 596 | 5.23 (±0.58) | 8 |
| 29 | Asiatic brush-tailed porcupine *Atherurus macrourus* \* | 3 | 0.03 (±0.02) | 2 |
| 30 | Indian peafowl *Pavo cristatus* | 640 | 6.26 (±1.04) | 5 |
| 31 | Red junglefowl *Gallus gallus* | 1162 | 11.24 (±1.16) | 0.78 |
| 32 | Kalij pheasant *Lophura leucomelanos* | 300 | 2.87 (±0.70) | 0.98 |
| 33 | Indian hare *Lepus nigricollis* | 92 | 0.81 (±0.17) | 2.3 |
| 34 | Hispid hare *Caprolagus hispidus* \* | 8 | 0.07 (±0.06) | 2.25 |
| 35 | Capped langur *Trachypithecus pileatus* | 12 | 0.11 (±0.05) | 10 |
| 36 | Assamese macaque *Macaca assamensis* \* | 6 | 0.05 (±0.02) | 8.5 |
| 37 | Rhesus macaque *Macaca mulatta* | 577 | 5.07 (±1.12) | 8 |

Supplementary Fig. 1Range-wise (Panbari, Bansbari, and Bhuyanpara) beat level clouded leopard encounters by forest officials in Manas National Park.

Supplementary Fig. 2 Map (Manas National Park) showing range-wise beat level clouded leopard sightings by forest officials along with photo-captured clouded leopards through camera-trapping.

Supplementary Fig. 3 Recaptures of individual clouded leopards in Manas National Park.



Supplementary Table 2 The results of population closure using closure test for camera-trap data of the mainland clouded leopard in Manas National Park.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sampling period | Number of independent records (right flank) | Number of individuals (right flank) | Sampling days | Statistic (z) | *p* |
| Sampling Period: December 2017 – May 2018 |
| December 2017 – May 2018 | 10 | 5 | 153 | -2.462005195 | 0.006908133 |
| March 2018 – May 2018 | 9 | 4 | 88 | -2.04616604 | 0.02037002 |
| April 2018 – May 2018 | 9 | 4 | 49 | -1.2569204 | 0.1043912 |

Supplementary Table 3 Clouded leopard density estimates (with associated SE and CI) per 100 km2 from maximum-likelihood-based SECR in Manas National Park. Abbreviations used are D: Density, g0: home range centre, and σ: movement.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | Estimate | SE | Lower CI | Upper CI |
| D | 1.728461 | 1.27 | 0.48 | 6.27 |
| g0 | 0.001615434 | 0.0009 | 0.0005 | 0.0051 |
| σ | 1.92927 | 0.72 | 0.95 | 3.91 |

Supplementary Table 4Beta coefficients with standard errors, z value, and Pr(>|z|) of the habitat, anthropogenic, and ecological variables of clouded leopard habitat use in Manas National Park. Significance codes: 0 – ‘\*\*\*’, 0.001 – ‘\*\*’, 0.01 – ‘\*’, 0.01 – ‘\*’.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variables | β Estimate | Std. error | z value | Pr(>|z|) | Significance codes |
| Habitat variables |
| canopy cover | 2.3659 | 0.6816 | 3.4710 | 0.0005 | \*\*\* |
| elevation | -0.2808 | 0.3051 | -0.9200 | 0.3570 |   |
| ndvi | 1.7132 | 0.4455 | 3.8450 | 0.0001 | \*\*\* |
| distance to grassland | 0.3057 | 0.2157 | 1.4170 | 0.1560 |   |
| Anthropogenic variables |
| distance to settlements | -0.0086 | 0.2473 | -0.0350 | 0.9720 |   |
| distance to roads | 0.0008 | 0.0039 | 0.2020 | 0.8400 |   |
| Ecological variables |
| Species groups |
| dominant predators (tiger, leopard) | 0.0244 | 0.2388 | 0.1020 | 0.9190 |   |
| small carnivores (civets, mongooses, martens) | -0.0268 | 0.2569 | -0.1040 | 0.9170 |   |
| civets | 0.0062 | 0.2449 | 0.0260 | 0.9800 |   |
| mongooses | -0.0747 | 0.3095 | -0.2410 | 0.8090 |   |
| medium prey (wild boar, northern red muntjac) | 0.0149 | 0.2304 | 0.0650 | 0.9490 |   |
| small prey (hares, porcupines, galliformes, primates) | 0.4250 | 0.1595 | 2.6640 | 0.0077 | \*\* |
| hares | -0.1032 | 0.3291 | -0.3140 | 0.7540 |   |
| porcupines | 0.1761 | 0.1813 | 0.9710 | 0.3310 |   |
| galliformes | 0.5043 | 0.1285 | 3.9250 | 0.0001 | \*\*\* |
| primates | -0.3489 | 0.6317 | -0.5520 | 0.5810 |   |
| Species |
| tiger | 0.1153 | 0.2029 | 0.5680 | 0.5700 |   |
| leopard | -0.1416 | 0.3359 | -0.4220 | 0.6730 |   |
| wild boar | 0.0738 | 0.1567 | 0.4710 | 0.6380 |   |
| northern red muntjac | -0.5939 | 0.6134 | -0.9680 | 0.3330 |   |
| indian hare | -0.1032 | 0.3291 | -0.3140 | 0.7540 |   |
| himalayan crestless porcupine | 0.1761 | 0.1813 | 0.9710 | 0.3310 |   |
| indian peafowl | -3.7165 | 3.2060 | -1.1590 | 0.2460 |   |
| red junglefowl | 0.3098 | 0.1304 | 2.3750 | 0.0175 | \* |
| kalij pheasant | 0.4414 | 0.1579 | 2.7960 | 0.0052 | \*\* |
| rhesus macaque | -0.3489 | 0.6317 | -0.5520 | 0.5810 |   |
| large indian civet | -0.7396 | 0.7681 | -0.9630 | 0.3360 |   |
| small indian civet | 0.0296 | 0.2317 | 0.1280 | 0.8980 |   |
| asiatic palm civet | 0.2654 | 0.1731 | 1.5330 | 0.1250 |   |
| crab-eating mongoose | 0.0034 | 0.2450 | 0.0140 | 0.9890 |   |
| small indian mongoose | -0.0264 | 0.2815 | -0.0940 | 0.9250 |   |
| indian grey mongoose | -17.2600 | 1899.0430 | -0.0090 | 0.9930 |   |
| yellow-throated marten | -4.0850 | 395.1500 | -0.0100 | 0.9920 |   |

Supplementary Fig 4 Comparison of density estimates (D; individual/100 km2) and standard errors (SE) from published studies of mainland clouded leopards based on spatially explicit capture-recapture analysis.

Supplementary Table 5 Density trends (individuals per 1002 km with associated SE) of top predators, i.e., tiger and leopard, in Manas National Park. NA, data not available.

|  |  |  |  |
| --- | --- | --- | --- |
|   | 2010–2011 | 2013–2014 | 2018–2019 |
| Tiger *Panthera tigris* | 1.79 ± SE 1.14 (Jhala et al., 2011) | 1.82 ± SE 0.63(Jhala et al., 2015) | 3.3 SE ± 0.6(Jhala et al., 2020) |
| Leopard *Panthera pardus* | 3.4 ± SE 0.68(Borah et al., 2014) | NA | 3.69 ± SE 0.68(Jhala et al., 2021) |

**References**

BORAH, J., SHARMA, T., DAS, D., RABHA, N., KAKATI, N., BASUMATARY, A., et al. (2014) Abundance and density estimates for common leopard Panthera pardus and clouded leopard *Neofelis nebulosa* in Manas National Park, Assam, India. *Oryx*, 48, 149–155.

JHALA, Y.V., QURESHI, Q. & GOPAL R. (2015) The status of tigers, copredators & prey in India 2014. National Tiger Conservation Authority, New Delhi & Wildlife Institute of India, Dehradun.

Jhala, Y.V., Qureshi, Q. & Nayak, A.K. (2020) Status of tigers, copredators and prey in India, 2018. National Tiger Conservation Authority, Government of India, New Delhi, and Wildlife Institute of India, Dehradun.

Jhala, Y.V., Qureshi, Q. & Yadav, S.P. (2021) Status of leopards, co-predators, and megaherbivores in India, 2018. National Tiger Conservation Authority, Government of India, New Delhi, and Wildlife Institute of India, Dehradun.

Jhala, Y.V., Qureshi, Q., Gopal R. & Sinha, P.R. (2011) Status of the Tigers, Co-predators, and Prey in India, 2010. National Tiger Conservation Authority, Govt. of India, New Delhi, and Wildlife Institute of India, Dehradun.

Karanth, K.U., & Sunquist, M.E. (1992) Population structure, density and biomass of large herbivores in the tropical forests of Nagarahole, India. *Journal of Tropical Ecology*, 8, 21–35.

Menon, V. (2003) A Field Guide to Indian Mammals. Christopher Helm, London, UK.

Prater, S.H. (1971) The Book of Indian Animals. Bombay Natural History Society, Mumbai, India.