ORIGINAL ARTICLE   **OPEN ACCESS**

Managing Human-Leopard Interactions in Urban Guwahati

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ABSTRACT
Human-Leopard Conflict frequently becoming a severe threat to the global existence of this endangered species. Given the current rate of human population increase in Greater Guwahati's urban environments, growing resource demand, and rising need for access to land, it is clear that human-wildlife conflicts will not be abolished anytime soon (i.e., greed for land, habitat destruction, and the extent of encroachment). As a result, it is critical to have a better understanding of the available conflict resolution approaches. Guwahati, the biggest city in North-east India, is also home to a diversity of animals. Leopard-human conflicts have increased in frequency over the past few years, particularly with the Common Leopard (Panthera pardus fusca). As a result, detailed monitoring of the leopard population and the factors that contribute to conflicts has been implemented in an effort to reduce the tangible losses to both leopards and humans.
Keywords:*Indian common leopard, human-leopard conflicts, camera trapping, urban wildlife*

INTRODUCTION

The Indian Common Leopard (*Panthera pardus fusca*), which is listed as a Schedule 1 species under the Indian Wildlife (Protection) Act of 1972, is regarded by the IUCN as being Near Threatened (IUCN 2003). Human closeness is occasionally inhibited by this elusive, highly adapted, and solitary species, which can result in disputes with losses for both parties (1). Growing leopard-human confrontations have been observed over the past few decades in many places of the world (2). Guwahati, India's capital city, is located on the southern bank of the Brahmaputra River. For the past few years, the conflict has grown in Guwahati, particularly in Silpukhuri, Pandu, Boragaon, Jalukbari hills, East Gotanagar Maligaon, Central Gotanagar Maligaon, Maligaon Gaushala Park, West Gotanagar Maligaon, Adimgiri, Fatasil, Gotanagar, Nilachal, Narakashur, South Kalapahar, and Chitrachal hills. This growing conflict can be related to the metro's growing human population, which has resulted in decreased habitat and natural prey base. Guwahati is bordered by 5 hillocks and 7 Reserve Forests, which provide habitat for leopards. Guwahati Metropolitan City's urban environments have evolved dramatically in recent decades as a result of massive rural-to-urban population movement, industrialisation, and the relocation of the capital from Shillong to Guwahati. Unauthorized human settlement of five hillocks and seven Reserve Forests in and around Guwahati City, development of high-rise buildings, roads and highways, airports, and so on. However, the increased threat and casualties of man-leopard combat in the region, along with rampant destruction of Reserve Forests in the city hills, has pushed animals to the edge of extinction, necessitating immediate conservation action. The general purpose of this study is to determine the population of common leopards and to comprehend the elements that contribute to leopard-human conflict in Guwahati (Assam). The report also looks into the effect on urban animals. Land use and land cover maps based on field data have been widely used to build a spatiotemporal vulnerability map that will serve as a standard for future wildlife conservation and management in the vicinity. Because of how serious the situation is right now, an emergency action plan must be prepared to reduce conflict between humans and leopards while also conserving the leopards that are already there. This necessitated first-hand knowledge of the location of leopard presence, an estimation of abundance, and a mapping of regions according to the intensity of fights. Large carnivore population monitoring is challenging to carry out since they frequently are nocturnal, nocturnal, elusive, and travel great distances (3).

STUDY AREA

In Guwahati Metropolitan City (Fig.1) is regarded as the major city and a hinterland of North-East India due to its key role in trade and business, education, and other cultural activities. Guwahati City was established as a municipal town in 1865 and was incorporated as a city in 1974. Guwahati's population was only 8394 in 1891, but it grew tremendously to 5,84,342 in 1991, according to the census. The Guwahati Municipal area, which was 7.86 square kilometres in 1951, has grown to 216.19 square kilometres inside the Guwahati Municipal Corporation (4). According to the Guwahati Municipal Corporation, the Guwahati City weighs 216.79 square kilometres, while the Master Plan for Guwahati, enacted in 1965 under Section 10 of the Assam Town and Country Planning Act, scales 261.77 square kilometres (or 262 square kilometres) roughly (5).
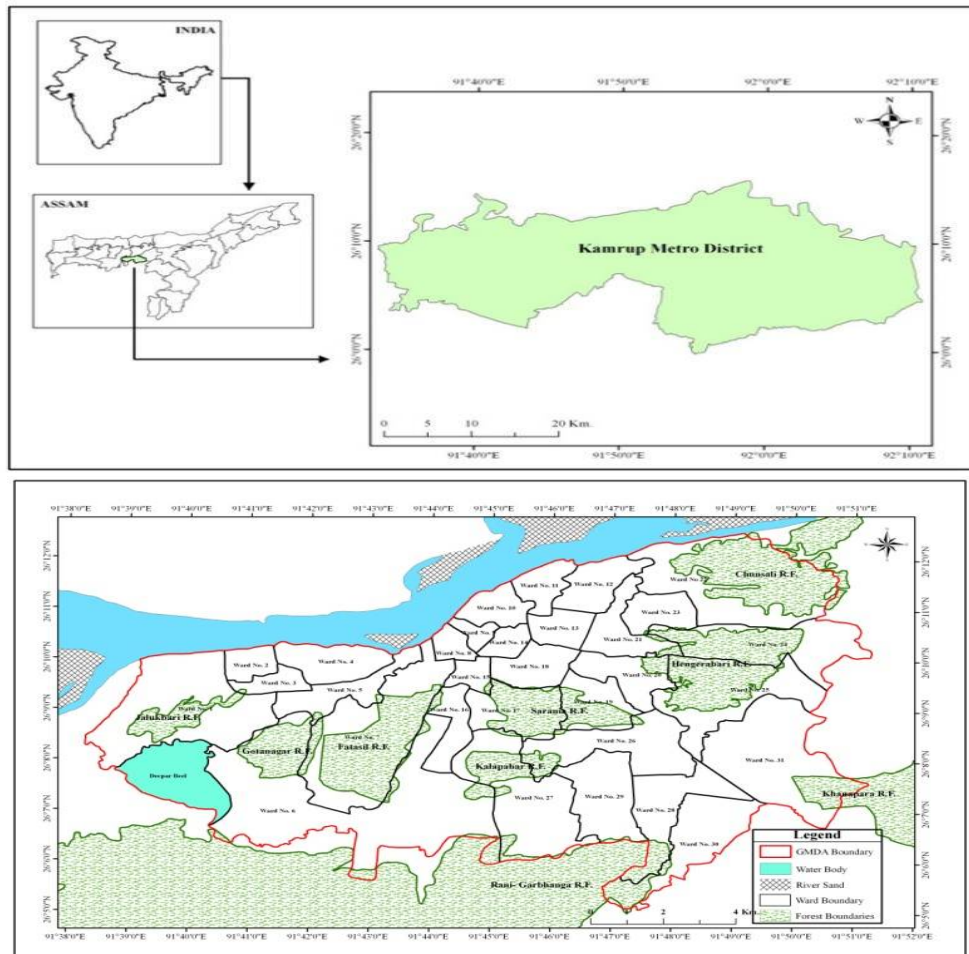
Fig. 1: Maps of the Guwahati Metro showing the study area.(Source: Field study)

MATERIAL AND METHODS
Methodology

An intense diurnal and nocturnal field research was conducted from 22nd October 2015 to 9th January 2021 to determine the distribution of Indian Leopard (Panthera pardus fusca) in 7 Reserve Forests (Table 1) and 5 hillocks, namely Nilachal, Narakasur, Chunsali, Chitrachal, and Japorigog. During the research period, a questionnaire survey was distributed to 335 families. The study used both field-based raw data and Forest Department data on wild-caught, conflict, translocations, capture and release, injured (both Leopard and human), mortality incidences, road mortalities, revenge killing incidences, accidental death, and rescued data, as well as information from semi-structured interviews and a questionnaire survey. The technique for the field survey was based on (6), with minor modifications to account for local circumstances. A scat sample study (7) was conducted over the Gotanagar Hill range, and rake marks on trees and ground, carcasses, and footprints were also recorded to corroborate the presence of leopards. (8, 9, 10). A random sampling method was used to collect any evidence of leopard presence (scat and pugmark) inside the research region (Fig.1).

Camera Trapping for Population Estimation and Recognition of Species
The trail camera, Cuddeback Digital-Silver Infra-Red and Cuddeback Digital-Blue Series Exchange Flash System Long Range Color of 20 Megapixels with 100 ft. Flash Range, was utilised. Full HD capture with 14 Trigger speed, Night Vision mode with motion sensor, had been utilised extensively to collect photographs and film of leopard movements from the stratified research location. A pilot study was done earlier at the planned site where the incidence of seeing was higher. Camera traps were employed extensively after (11) with a minor modification to record photos and film of leopard movements from the stratified research locations.

The photo capture information on common leopards of Guwahati was obtained from an ad-hock camera trapping conducted across the study sites. Sampling was carried out in both winters and summers between 22nd October, 2015 to 9th January, 2021 across the study sites. Four trap cameras were used (without baits) during the sampling period (Table 2) The cameras were operational for 24 hours in a day (12, 13).

Table 1: Reserve Forests of Guwahati City

Name of RF's under Guwahati Range	R.F Codes	Latitudes / Northings	Longitudes/ Eastings	Elevation (meters)	Total area of RF's. (in Ha.) 2018	Area under Encroachment (in Ha.) 2018	Number of Households 2018	No. of Family members 2018
Gotanagar R.F	RF1	26° 8'10.91"N	91°40'58.59"E	171	171	133.6	1992	1820
Fatasil R.F	RF2	26° 8'20.31"N	91°44'35.07"E	223	670.44	222	6302	4723
Khanapara R.F	RF3	26°7'31.038"N	91°50'38.156"E	275	9.87	398	4325	1798
Jalukbari R.F	RF4	26° 8'46.21"N	91°39'20.29"E	151	97.7	2.6	9	42
S. Kalapahar R.F	RF5	26° 7'56.19"N	91°44'35.07"E	124	70	60	1279	1098
Sarania Hill RF	RF6	26°10'38.94"N	91°46'6.04"E	163	7.99	3	42	90
Hengrabari R.F	RF7	26° 9'56.45"N	91°47'43.48"E	121	628	385	3392	4200
Sub-total					1625.13	1203.6		

Table 2: Camera Trapped GPS locations of Common Leopards in different spots of the study areas

SN	Reserve Forests	Place	Latitude	Longitude	Year	Season
		Camera Trap GPS Records 2015 -2018 / Guwahati Metro				
1	Fatasil R.F	Garobasti	26°09'12.0"	91°43'13.6"	2015	Summer
2	Fatasil R.F	Doimogiri	26°09'21.8"	91°43'13.3"	2016	Winter
3	Fatasil R.F	Rupnagar, Dhireswari Path	26°09'27.7"	91°45'47.5"	2017	Summer
4	Fatasil R.F	T.V. Tower, near Nurse Hostel	26°09'13.19"	91°46'5.78"	2016	Summer
5	Fatasil R.F	4 APBN; near Suhasini Appt., Narakakhur Hill, Rupnagar	26°08'59.82"	91°45'45.00"	2018	Winter
6	South Kalapahar Hill R.F	Siva Temple, Hotel V.I.P	26°15'34.54"	91°74'15.35"	2015	Summer
7	South Kalapahar Hill R.F	Vinovanagar, Hill side	26°07'56.19"	91°44'35.07"	2017	Summer
8	South Kalapahar Hill R.F	Vinovanagar, Hill side	26°15'19.13"	91°74'09.85"	2018	Winter
9	Gotanagar R.F	Maligaon Goshala	26°08'43.09"	91°41'46.01"	2015	Summer
10	Gotanagar R.F	Maligaon, Krishna Nagar	26°08'42.09"	91°42'02.04"	2015	Winter
11	Gotanagar R.F	Adimgiri Hill	26°09'27.06"	91°42'42.03"	2016	Winter
12	Gotanagar R.F	Madhabdev Nagar, Adimgiri Hill	26°08'30.01"	91°41'36.09"	2017	Summer
13	Gotanagar R.F	Kalapani	26°08'16.02"	91°42'35.02"	2018	Winter
14	Gotanagar R.F	Dry Well point, West Boragaon Hill top	26°07'42.16"	91°40'57.98"	2018	Winter
15	Jalukbari Hill R.F	G.U. Staff Quarter near Power house	26°15'44'32"	91°67'51.48"	2015	Summer
16	Jalukbari Hill R.F	Ayurvedic College	26°15'09.39"	91°66'07.77"	2017	Summer
17	Jalukbari Hill R.F	AEC Boys Hostel	26°14'91.69"	91°66'53.64"	2018	Summer
18	Nilachal Hill (Pandu)	House of Bijoy Nepali, near B.Ed. College, Pandu Port	26°10'12.14"	91°41'32.14"	2015	Winter
19	Pandu Temple Ghat (River Hill Side)	near Subedar's House/ adj. Gammon Pipe	26°10'12.78"	91°41'31.33"	2016	Winter
20	Pandu Temple Ghat	House of Monica Simond Kakati / Rly Employee (Retd.)	26°10'13.69"	91°41'29.22"	2018	Winter

Identification and Status of Indian Leopard (Panthera Pardus Fusca)
The species in question is identified after Pocock (14, 15) Species concern status is determined using the IUCN database and Catalog of Life (www.iucn.org) (www.catalogoflife.org).

Collection of Data
People living in and near the research area were surveyed using a questionnaire, and interviews were undertaken to gather information about livestock losses from leopard predation and instances of leopard-human conflict (Fig.2.4).
During the field research period, which runs from 2015 to 2018, the survey periods were separated into 4 seasons (16).

Fig. 2.4 . Questionnaire survey among the Locals & households of the study area

Secondary data Information on leopard predation on livestock, wild capture, and capture has been gathered from many parties, including the Assam State Zoo and the Forest Department. Areas with high, medium, and low levels of conflict had been determined based on this data.

Pug Mark Survey
The big cat species produce a lot of spoors that may be seen, including tracks and scats (Smallwood and Fitzhugh 1995, Beier and Cunningham 1996 (17). Track counts and pug mark identifications were used as equally accurate population estimates (Fig. 2.5), (18). For a trustworthy image of the leopard distribution, a spraint (scat) sample study over the Gotanagar, Fatasil, Jalukbari, South Kalapahar, Narakasur, and Nilachal Hill range had been carried out. Additional evidence supporting the presence of leopards includes scratch marks on trees and the ground, carcasses, and footprints (19). Numerous caves were searched for the closest pugmark, cadaver, scat, leftover prey bone fragments, and vomit in order to identify the leopard pocket (gush back of the stomach). The digital camera was utilised extensively during the survey to take pictures of the critical killing places, whether they were inside or outside the grazing area, and the GPS coordinates of the spots were also recorded. Counting of pug marks and photographic evidence of scats has been displayed at Plate 5.1 A, Plate 5.1 B, Plate 5.1 C for pug marks and (Plate 5.2 A), (Plate 5.2 B), (Fig. 5.2 A), (Fig. 5.2 B). The pug markings showed the presence of both the male and female as specified by the formula
If PML – PMB < 1.5 cms likely to be Male Leopard; # If PML – PMB > 1.5 cms likely to be Female Leopard
Where, **PML** = Pug Mark Length and **PMB** = Pug Mark Breadth. Normally, females are larger than that of its male counterpart (18).

Fig: 2.5: A scaled casted pug mark of common leopard from Gotanagar Reserve Forest (R.F 1),
(18).

Conflict Level Zones

Based on the field survey, camera traps, secondary records from Forest Department and other stakeholders a detailed conflict location map both within and outside the reserve forest areas have been prepared using GIS and suitable cartographic techniques
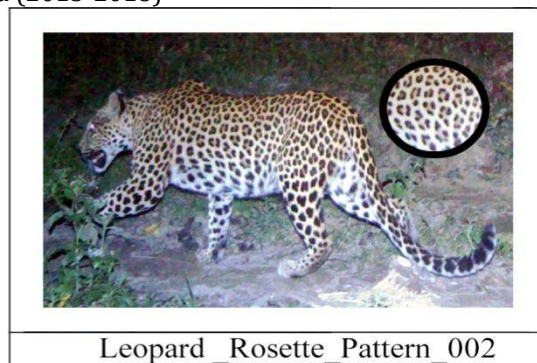
RESULTS AND DISCUSSION

Based on the field survey, camera traps, secondary records from Forest Department and other stakeholders a detailed conflict location map both within and outside the reserve forest areas have been prepared using GIS and suitable cartographic techniques (Figure 5.1)
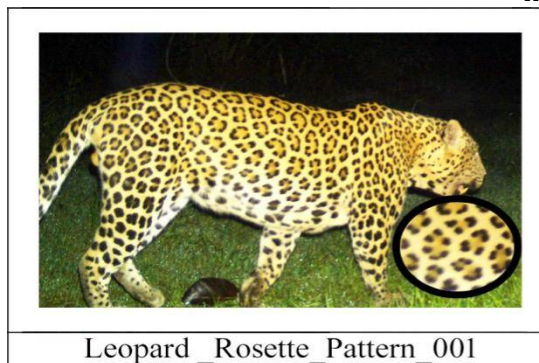
Camera trap

The Camera trapping records been depicted in the table 3. Camera trapped images of leopards in different locations have been depicted in the (Plate 3.1.1). The highest number of sightings (12 times) recorded in the Gotanagar area followed by Fatasil Reserve Forest at 10 (2) (Table 3). Individuals were recorded different from one another (Plate 3.1.2). A total number of 168 times trapping efforts were done in 20 different locations (Table 2) during the survey period, of which 131 numbers of total records of leopard were obtained (Table 3, Plate 3.1.1 and Plate 3.1.2). The individual identity was made based on the rosette pattern of markings (Plate 3.1.2). Camera trapping method allowed to identify 10 numbers as male, 2 as female and the others remained unidentified (Plate 3.1.3) (13)..

Table 3.1.1: Camera Trapped Records of Common Leopards from 2015 to 2018

Sl. No	Reserve Forests& Hills	2015		2016		2017		2018		Total records
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	
1	Fatasil R.F	1	1	2	1	2	1	1	1	10
2	South Kalapahar Hill R.F	1	1	2	Nil	1	Nil	Nil	1	6
3	Gotanagar R.F	2	2	2	1	1	1	2	1	12
4	Jalukbari Hill R.F	1	1	1	Nil	1	1	2	2	9
5	Nilachal Hill (Pandu)	1	Nil	2	Nil	Nil	1	2	1	7
6	Pandu Temple Ghat	Nil	1	Nil	Nil	2	Nil	1	2	6
	Total									131
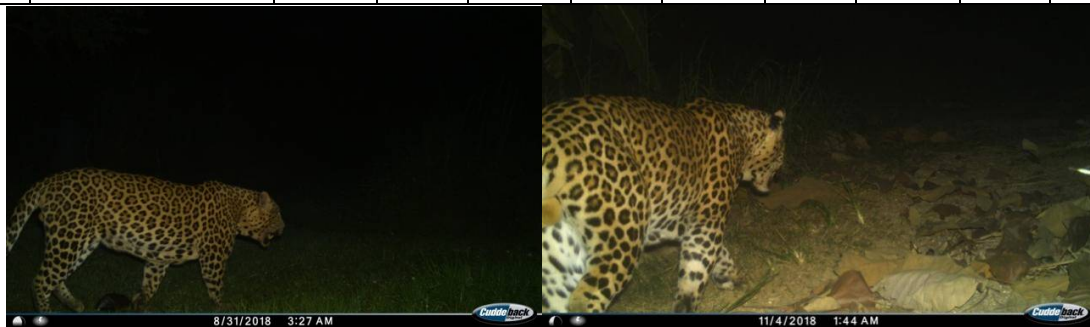
Plate-3.1.1 Camera Trapped Images of Common Leopard in different localities of the study area at Fatasil Reserve Forest; and South Kalapahar Reserve Forest, Guwahati (Metro), Assam, India (2015-2018)

Leopard _Rosette_Pattern_001   Leopard _Rosette_Pattern_002

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Plate 3.1.3: Identification of Male Leopard from the Camera trapped photographs
(M=Male Leopards**)**

Pug Mark

The pug mark obtained from various locations of the study area (Table 3.1.2) were analysed, showed square type of structure for Male Leopard and elongated for female (Plate 3.2.1 & Plate 3.2.2).Here, 36 different pugmarks were identified in the study area, out of which 8 numbers of pugmarks were preserved by casting them with (plaster of Paris powder) where 6 numbers of pug marks casted were found to be Male and 2 numbers of pug marks as female.

By taking good quality of plaster of Paris powder in a vessel, mixing it thoroughly with adequate amount of water. By securing the borders of the pug mark to be casted over the earth with wooden stick measuring 10 cm x10 cm x 3 cm thickness. By pouring the water mixed plaster of Paris in the pug mark depressions and allowing them for few hours to get firmly solidify, and later on, the plaster of Paris was removed carefully after it gets rigid enough to remove it from the ground and mentioning the pug marks permanent markers for detailing the shape, size and length to get more highlighted for its probable gender identification purposes (20) and (WWF – Pakistan 2005 - 2007- Preliminary study to know leopard population in and around Ayubia National Park).

Leopard _Casted_pug_marks (female)007   Leopard _Casted_pug_marks (male)008
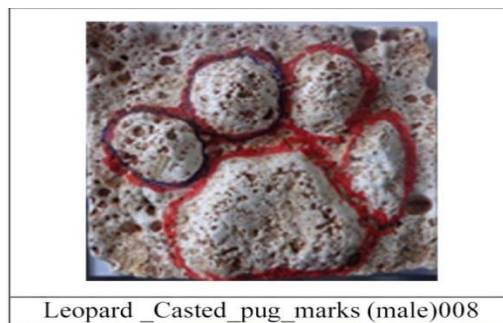
Plate-3.2.1 : Identification of casted pug marks of individual Leopards from different locations in the study sites, Guwahati (Metro), Assam, India (2015-2018)

Leopard_pug_marks (female)007   Leopard_pug_marks (male)008
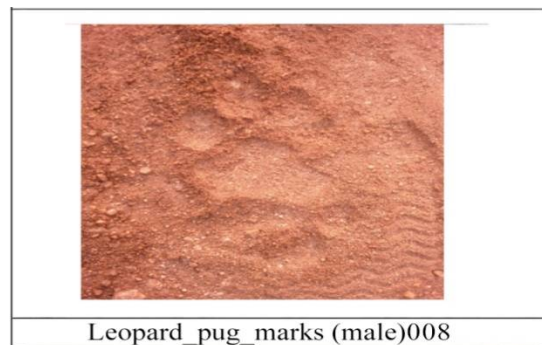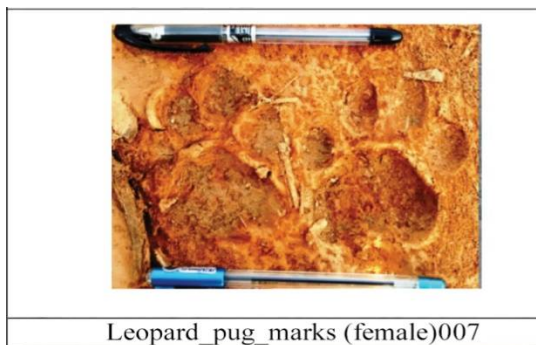
Plate-3.2.2: Identification of pug mark impression on the ground of individual Leopards from different locations in the study sites, Guwahati (Metro), Assam, India (2015-2018)

Table 3.1.2: Identified Pug marks of Leopards collected during 2015-2018 from the study area								
Total	Reserve Forests							Total
	RF1	RF2	RF3	RF4	RF5	RF6	RF7	
Adult Male	1	5	1	1	1	0	0	9
Adult Female	2	5	0	1	0	0	0	8
Male Cub	0	1	0	1	0	0	0	2
Female Cub	0	1	0	0	0	0	0	1
Total	3	12	1	3	1	0	0	20

Conflict Level Zones

Human-Leopard Conflict: The total number of Human-Leopard Conflict in seven different study sites were depicted in the (Table 3.3). The highest number of conflict records was obtained in the wards 6 and 7 and depicted in the (Fig.3.3 A). Records and comparison of the same are demonstrated in the (Fig.3.3 A) and (Fig. 3.3 B).
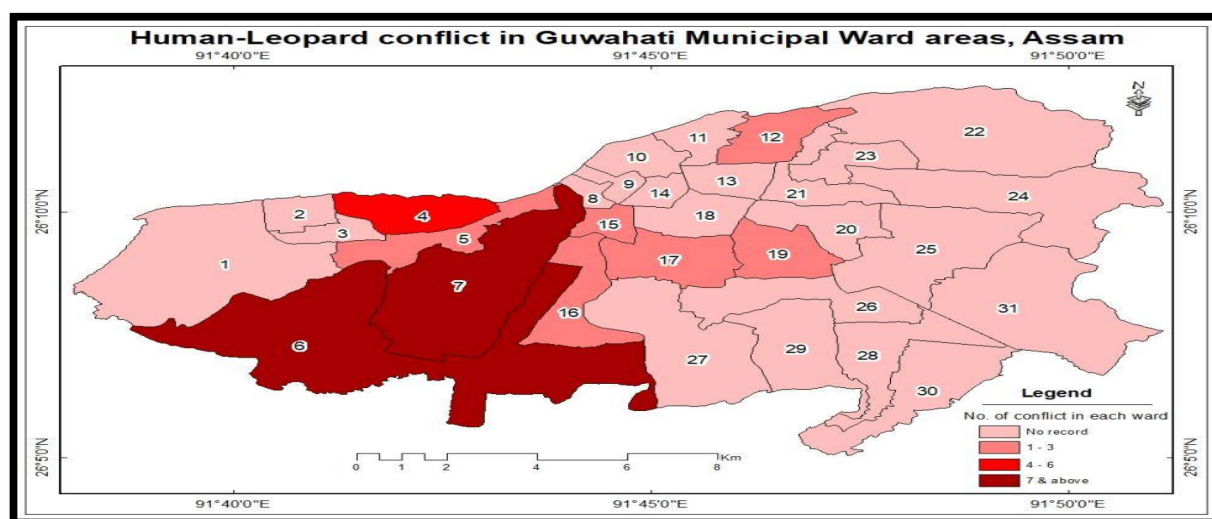

Fig. 3.3 A: Ward-wise records of Human-Leopard Conflict obtained from the Guwahati City

Table 3.3: Records of Human-Leopard Conflict during 2007-2015 & 2015-2018 in the study area

Years	Reserve Forests							Total
	RF1	RF2	RF3	RF4	RF5	RF6	RF7	
2007-2015	5	3	0	0	2	3	0	13
2015-2018	3	4	0	0	0	0	0	7
Total	8	7	0	0	2	3	0	20

Records of Human-Leopard Conflict from the field survey (2015–2018) and stake holders i.e., from Department of Forest, Govt. of Assam (2007-2015) were depicted in the (Fig. 3.3 A), (Table 3.3) and (Fig. 3.3 B) (Fig. 3.3 C).
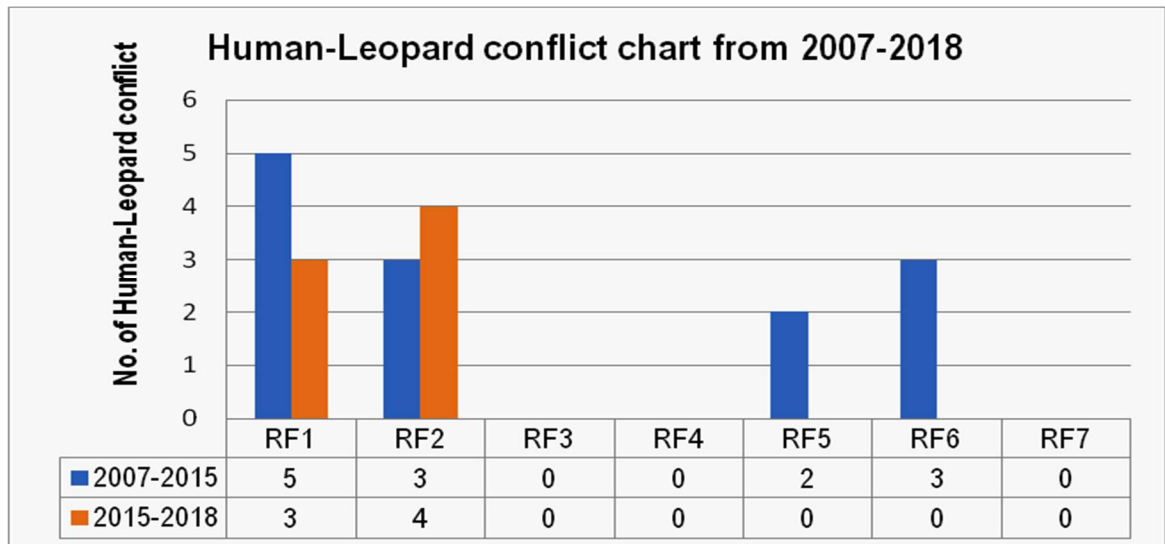
R.F 1 – Gotanagar R.F; R.F 2 – Fatasil R.F; R.F 3 – Jalukbari R.F; R.F 4 – South Kalapahar R.F;
R.F 5 – Sarania R.F; R.F 6 - Hengrabari R.F; R.F 7 – Garbhanga R.F
**Fig.3.3 B: Histogram showing the Human-Leopard Conflict records from the study areas of
Guwahati Metro and its adjoining hillocks**

Fig. 3.3 C : Photographic records of Human-Leopard Conflict from the field survey (2015–2018)

CONCLUSION

The increase in human-leopard conflict in and around Guwahati's reserve forests, Assam, is owing to human growth and encroachment into leopard habitat. To lower the current degree of conflict in both responders, a complete investigation of leopard population structure and size is necessary, as well as the installation of alerting devices on the edge of the selected location to monitor their activity. The current study showed that human-leopard interactions in Guwahati have a high risk of conflict. We identified that the main causes for the intensified human-leopard interactions were the increased human disturbance that has changed the leopards' habitat, human activities in leopards' territories, and mismanagement of livestock. The results gives an insight that managing human-leopard interactions in Guwahati should include measures such as enforcing existing environmental laws, creating awareness programs in the local communities, managing livestock care, and implementing wildlife conservation initiatives. Ultimately, such

measures can help reduce the risk of conflict and can ultimately lead to a more harmonious coexistence between humans and leopards in the region.

ACKNOWLEDGEMENT

REFERENCES

1. Bharali KK. (2008). Managing Human-Wildlife Conflict and Conservation Threats in and Around the Urban Landscapes of Greater Guwahati, Assam, India.
2. Bharali KK, Sharma DK, Sahariah D, Lokeshwor Y. (2000). Nowhere to live: squeezing habitat and human-leopard conflicts in Maligaon, Guwahati, Assam.
3. Schipper J, Chanson JS, Chiozza F, Cox NA, Hoffmann M, Katariya V, Lamoreux J, Rodrigues AS, Stuart SN, Temple HJ, Baillie J. The status of the world's land and marine mammals: diversity, threat, and knowledge. Science. 2008 Oct 10;322(5899):225-30.
4. Nath, H., Bhattacharjee, D & Bezbaruah, S. (2001) *Water Supply in Greater Guwahati: Problems and Prospects. Guwahati: The Gateway to the East,* Assam, India. Concept Publishing Company, New Delhi – 110059, India, 55 – 80
5. Singha, K. (2010) Effects of land-use change in Reserve Forest areas of Greater Guwahati, M.Phil. Dissertation, Gauhati University, Guwahati.
6. Karanth K. U, Walston J, Stokes E (2010) Avoiding the Unthinkable: What will it cost to prevent tigers becoming extinct in the wild? Washington, D.C.: Global Tiger Initiative, World Bank, and Wildlife Conservation Society. 126 p.
7. Mondol, S., et al. (2009) "A panel of microsatellites to individually identify leopards and its application to leopard monitoring in human dominated landscapes." *BMC genetics* Volume 10(1) pp. 1-7.
8. Rabinowitz, A (1997). Wildlife Field Research and Conservation Training Manual. New York Wildlife Conservation Society.
9. Rodgers, W.A., Johnsingh, A.J.T., Panwar, H.S (1991). Ecology and conservation of large felids in India. In: N. Maruyama et al. (Eds.), Wildlife conservation: present trends and perspectives for the 21st century. Proceedings of the International Symposium on wildlife conservation in Tsukuba and Yokohama, Japan, 21–25, August 1990, pp.160–166.
10. Jhala, Y (2001) Evaluation of pug mark census technique, Wildlife Institute of India, Dehradune, India.
11. Mondal, K., Sankar, K., Qureshi, Q., Gupta, S. & Chourasia, P (2012) Estimation of population and survivorship of leopard *Panthera pardus* (Carnivora: Felidae) through photographic capture–recapture sampling in western India. *World Journal of Zoology*, **7**:30–39.
12. Jhala, Y., Gopal, R., Mathur, V., Ghosh, P., Negi, H. S., Narain, S & Qureshi, Q. (2021). Recovery of tigers in India: Critical introspection and potential lessons. *People and Nature*, *3*(2), 281-293.
13. Lahkar D, Harihar A, Singh A, MF, Begum RH (2021): Population density. Modelling of mixed polymorphic phenotypes: an application of spatial mark-resight models. Animal Conservation, 24(4), 709-716.
14. Pocock, R. I (1939*a) The fauna of British India, including Ceylan and Burma. Mammalia. Vol. 1. Primates and Carnivora (in part)*. Taylor and Francis, Ltd., London, 463.
15. Pocock, R. I (1939*b)* The races of jaguar (*Panthera onca*). *Novitates Zoologicae*, 41:406–422.
16. Borthakur M. Weather and climate of north east India. Northeastern Geographer. 1986;18(1):20-7. Catalog of life (www.catalogoflife.org). (Date of assessment: 16/05/2018)
17. Beier P, Cunningham SC. Power of track surveys to detect changes in cougar populations. Wildlife society bulletin. 1996 Sep 1;24(3):540-6.
18. Talwar R, Usmani A. Reading pugmarks: A pocket guide for forest guards. Tiger and Wildlife Programme, WWF India. 2005:49-51.
19. Ottino, P.& P. Giller (2004) Distribution, density, diet and habitat use of the otter in relation to land use in the Araglin valley, Southern Ireland. Biology and Environment: Proceedings of the Royal Irish Academy, 1(104b) : 1-17.
20. Lodhi A (2007) Conservation of leopards in Ayubia National Park Pakistan. (Master), University of Montana. https://scholarworks.umt.edu/cgi/viewcontent.cgi?article=1257&context=etd