



Review on: Diaries of Indian Leopard

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Abstract:

Leopards are most widespread member of Felidae family across the world, they are incredibly athletic and known for their climbing ability. We reviewed the literature on the Indian leopards to summarize the extent of research efforts and current ecological understanding. We summarized its evolution, ecological significance, phylogenetic tree, genetic diversity, status and distribution, food habit, breeding season, their various perspective of behavior (territorial behavior, stalking behavior and parental care) and conservation status. Human wild life conflict along with feeding habits were the most studied aspects while spatial ecology and behavior were the least studied aspects. Most of the studies were from protected areas as compared to non-protected areas. Indian leopards presently have patchy distribution. High densities of leopards were visible in prey rich areas. Indian leopards have smaller home ranges compared as to the African relatives. Leopards show activity peaks during dawn and dusk time of the day. Leopards co-exist with other large predator by fine adjustment in use of space time and food. Human – Leopard conflict was one of the most studied aspect. Indian leopards (*Panthera pardus fusca*) is a pre dominant field species native to the Indian subcontinent. They play crucial role as apex predators, regulating prey populations and maintaining ecosystem balance. However, fragmentation, habitat loss, poaching and human wildlife conflict pose significant threats to their survival. Understanding the biology and ecology of the Indian leopard is vital for effective conservation planning and ensuring the long term survival of this iconic species.

Keywords: Leopard, Carnivore Species, *Panthera pardus*, Evolution, Behaviour.

Introduction:

The name “Leopard” derives from the Greek word *leopardus*, a combination of *leon* (lion) and *pardus* (panther). Leopards are majestic big cats known for their distinctive spotted coat and stealthy hunting prowess [2, 4, 5]. They inhabit a variety of habitats across Africa and Asia, from dense forests to savannas [1]. With their agility, strength and keen senses, they’re formidable predators, capable of taking down prey much larger than themselves [3, 4, 6].

There are nine subspecies of leopards, which can be distinguished by the characteristics of their coat. Despite their names, the clouded leopard (*Neofelis nebulosa*) and snow leopard (*Panthera uncial*) are often considered separate species [2].

The leopard is a solitary animal of the bush and forest and is mainly nocturnal in habit although it sometimes basks in the sun [7, 20]. The leopard varies greatly in size and markings. The leopard can, however, grow much larger. The ground color is typically yellowish above and white below [12]. Dark spots are generally arranged in rosettes over much of the body and are without the central spot characteristic of the coat of the jaguar; the ground color within the rosettes is sometimes a darker yellow, and the size and spacing of the spots vary greatly [11, 13]. As a result of these differences in pattern, several races of leopard have been named. Leopards exhibit a range of color and pattern variations [8, 9]. Like many species of cats, leopards sometimes exhibit melanism, a genetic mutation that causes the skin and fur of the animal to contain large amounts of the dark pigment called melanin [10, 11]. Melanistic leopards are also known as black leopards. These leopards were once thought to be a separate species from non-melanistic leopards [18, 12, 14]. Leopards have shorter legs than many other species of big cats. Their body is long and they have a relatively large skull. Leopards are similar to jaguars in appearance but their rosettes are smaller and lack a black spot in the center of the rosette [15, 21].

SYSTEMATIC POSITION:

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Carnivora

Sub order: Feliformia

Family: Felidae

Sub family: Pantherinae

Genus: *Panthera*

Sub species: *P. p. fusca*

Species: *P. pardus*

(Meyer, 1794)

The leopard (*Panthera pardus*) belongs to the genus *Panthera*, which includes other big cats such as lion, tigers and jaguars. Here is an overview of the phylogeny of the leopard: [27, 100]

Kingdom: Animalia- Leopard are a part of the animal kingdom, characterized by multicellular organism that ingest food [100].

Phylum: Chordata- They belongs to the phylum chordata, which includes animals with a Notochord (flexible rod supporting the body) [100].

Class: Mammalia- leopard are mammals, characterized by mammary glands, hair and the ability to nurse their young [100].

Order: Carnivora- They classified under the order carnivore, indicating their specialization as carnivorous species. They prefer to intake animal flesh as their meal [100]. Most of the carnivores have relatively large brain and high levels of intelligence [27, 31]. It include strength, speed, keen senses for hunting as well as teeth and claws for capturing and tearing prey [31]. Canine teeth is an important features of all carnivores that helps to ripping, tearing and shearing flesh [27, 30, 31]. In some carnivore species they possess a few molar in the back of their mouths and sharp incisor in the front [31].

Family: Felidae- leopard belongs to the family Felidae, which encompasses all modern cats [31]. The skull structure and size is a key features that defers for each of the Felidae genera. They are morphologically similar with rounded, flat faces, facial whiskers and large eyes and large ears [17, 19].

Genus: Panthera- leopard are grouped under the genus Panthera along with other big cat. This genus includes a large muscular body with large skull and long tail, broad paws [17, 18, 19, 100].

Species: *Panthera pardus*- The specific species name for leopard is *Panthera pardus* [100].

Evolution:

The historical biogeography of the leopard is a complex issue, because the patterns supposed from fossils and from molecular data lack compatibility [22, 29]. Fossil evidence supports an African origin and suggests that leopards were already present in Eurasia during the Early Pleistocene [24]. Analysis of DNA sequences however, suggests a more recent, Middle Pleistocene shared ancestry of Asian and African leopards [24]. The leopard (*Panthera pardus*) is an example of a species that is currently distributed across only a fraction of its historical and ancient range [26, 30]. It is one of only a few large-bodied carnivore species that naturally occurs in a wide variety of habitats; from the Himalayan highlands to the Ethiopian desert, and from the Congo rainforests to the Amur taiga. Human persecution and hunting, habitat destruction and reduced prey availability have severely impacted the distribution of this elusive predator, and leopards are now extinct in large parts of their historic Asian and African distribution [55, 83].

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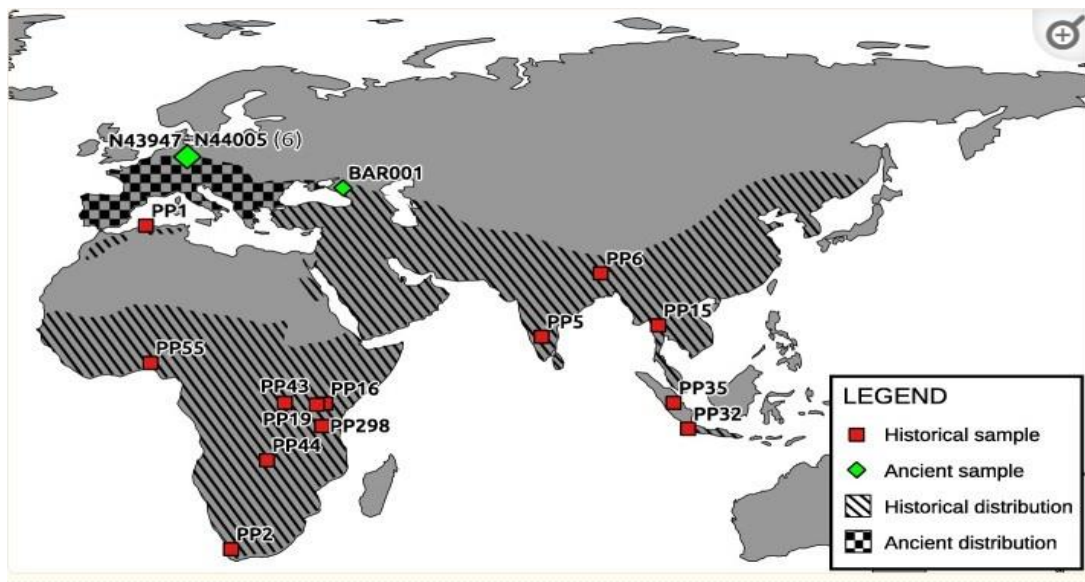


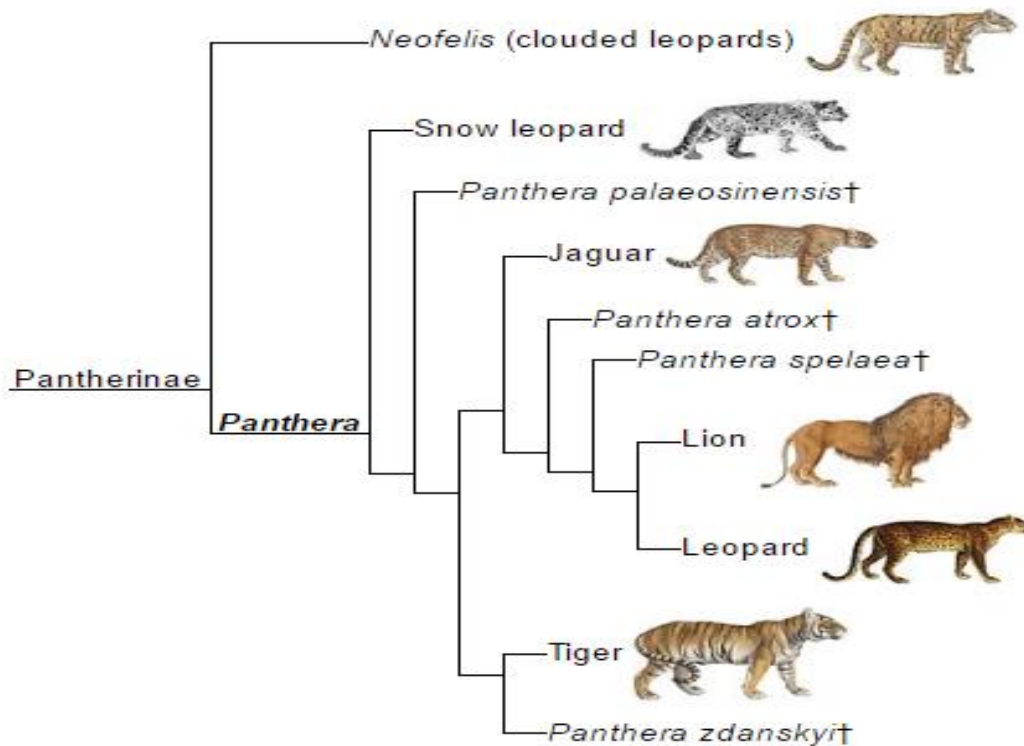
Fig: The historical and ancient distribution of Leopard

Distribution:

The leopard's geographic range spanned nearly the whole of Africa south of the Sahara, occupied parts of north and northeast Africa, and extended from Asia Minor through Central Asia and India to China and Manchuria. By 2019 the species had lost up to 75 percent of its former range [37, 49, 50]. Several large pockets, however, remained throughout sub-Saharan Africa, Iran, and the Himalayas, with smaller pockets scattered throughout Central Asia, India, Southeast Asia, eastern China and Manchuria, and the Korean peninsula. In addition, one tiny pocket of leopards persists in the Atlas Mountains [23, 34, 57].

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Phylogenetic tree of Leopard (*Panthera pardus*) :



Phylogenetically, leopard are closely related to other members of the genus *Panthera*, sharing common ancestry and evolutionary history with other big cats. Their phylogenetic relationship are studied using genetic analysis and morphological comparisons to understand their evolutionary development and relationship with other fields [32, 42, 50, 51, 59].

Genetic Diversity:

The amount of genetic diversity revealed in the leopards was comparable to or higher than those reported for other cat species, such as lions, cheetahs, jaguars, and pumas [37, 60]. The genetic variation in leopards, however, varied significantly across their geographical range [48, 49]. There may be bias in estimation of actual genetic diversity among leopard populations due to different and sometimes insufficient sample sizes [50]. Three populations (*P. p. saxicolor*; *P. p. japonensis* and *P. p. delacouri*) were represented only by captive-bred individuals and thus, the reported genetic estimates reflect the status of captive populations of these revised subspecies [25, 53, 61, 67].

The African leopards were the most genetically variable among all leopard subspecies by both mtDNA sequences and microsatellites [54, 63, 74]. Similar high diversity has been reported for Tanzanian leopards [38, 60, 64]. The lowest level of genetic variation in both types of markers was observed in the Far Eastern leopard *P. p. orientalis* [28, 33, 41, 62]. This population has a documented history of demographic and range reduction, and it is the most critically endangered leopard subspecies Sri Lankan leopards *P. p. kotiya*, which had previously been reported as showing diminished genetic diversity with several genetic metrics also showed relatively low levels of microsatellite variation The mtDNA diversity was somewhat low in *P. p. saxicolor* (mean number of pairwise differences was 0.50 and nucleotide diversity was 0.07%) [39, 40, 80, 81].

Size:

The average size is 50 to 90 kg (110 to 200 pounds) in weight, 210 cm (84 inches), excluding the 90-cm tail in length and 60 to 70 cm in shoulder height [36, 77, 83, 85].

	<u>Male</u>	<u>Female</u>
Body weight:	37- 90 kg	28-60 kg
Head and Body length:	3.0-6.3 ft.	3.0-6.3 ft.
Tail length:	1.9- 3.6 ft.	1.9-3.6 ft.
Life Span:	12-17 year	12-17 year

Pugmarks of Leopards:

- The pug marks of Male almost fits into a square.
- The pug marks of a Female fits into a rectangle.
- If the difference between PML and PMB is less than 1.5 cm, the pugmark is likely to be that of a Female [47, 83, 84, 85].

Habitat:

Leopard habitats include forests, subtropical and tropical regions, savannas, grasslands, deserts, and rocky and mountainous regions [56, 57]. They can live in both warm and cold climates. Of all the big cat species, leopards are the only known species that live in both desert and rainforest habitats [88, 89, 101, 105]. Leopards living in desert areas tend to be paler yellow in color than those that live in grasslands [102]. Leopards inhabiting grasslands are a deeper golden color. The range of the leopard is the most widespread of all the big cats [43, 101, 107]. Their range covers a large stretch of Africa, parts of the Middle East, and Asia, including China, India, and eastern Russia [45, 65, 99, 103].

Food Habit:

Leopards are carnivores, but their diet is among the widest of all the cat species. Leopards feed primarily on large prey species such as ungulates. They also feed on monkeys, insects, birds, small mammals, and reptiles. The diet of leopards varies based on their location [11, 59]. In Asia, their prey includes antelopes, chital, mantas, and ibex. Leopards hunt mainly during the night, their large eyes and dilated pupils allow them to see well in dark conditions. They are skilled at climbing and often carry their prey into trees where they feed or hide their catch for later use [51]. By feeding in trees, leopards avoid being disturbed by scavengers such as Jackals and Hyenas [80, 84]. When a Leopard captures large prey, it can sustain them for as long as two weeks. They are also fast and can run up to 36 mph. In comparison, the cheetah, the fastest land mammal, runs 50 to 80 mph. Leopards can leap 20 feet forward in a single bound and jump ten feet straight up [117]. They will leap and jump to capture prey, especially birds. Unlike most cats, leopards are strong swimmers. They are one of the few cats that like water. They are capable of killing prey larger than themselves [66, 68, 89, 92].

Breeding Season:

Leopards usually breed only once a year, but do not have a definite breeding season [69]. Leopard females mate for the first time at the age of 2 to 2½ years. Males start breeding at the age of 1½ years. Females are in heat (oestrus) for 5 – 13 days every 2 – 3 months [29].

During the breeding season, adult males and females will use scents to find each other. The male may follow a female around for several days before she is ready to breed. If she is not ready to mate when the male attempts, the female may attack her pursuer [99].

The gestation period is approximately 3 months and the female gives birth to a litter of 2 to 3 cubs on average. She will use a cave, a burrow or an opening in thick vegetation as a birthing den. The cubs are born vulnerable with sealed eyes and little hair [101, 77]. The mother will stay with her cubs for their first few days before venturing out to hunt. She will continue to move her cubs from one den to the next while she hunts until they are large enough to venture out with her [80].

At about three months of age, the cubs venture out with their mother to learn hunting and survival skills. By 12 to 18 months, the young leopards are typically ready to head out on their own [69, 93, 95, 113].

Spatial Ecology:

Spatial ecology is one of the least addressed subject in the case of Leopard. Indian leopard's home range were consistently smaller ranging from 8 km² to 62 km² and much small as compared to the African studies [102, 113]. Home ranges in case of large carnivore are found to be inversely related to pray availability. Difference between home ranges of male and female is reflected in some state. Inter sexual overlap in home ranges evident in studies of Indian leopard where male showed more overlap with female home ranges [49]. As compared to overlap. High resource availability in terms anthropogenic food resources and year round availability some crucial resources such as water might be responsible for such smaller ranges. Since carnivores are territorial therefore densities of conspecific may affect the home range size in carnivores. A review found that carnivore's home ranges were negatively correlated to their densities but presently there is no such studies on Indian leopard. Scientist found no decline in home ranges of males as compared to females. Later study found evidence for dispersal regulate strategy that female leopard decrease their home 8 size in response to increased density while males maintain large home ranges. Dispersal ecology is important in order to understand the population dynamics and to understand the social interaction among the large carnivores [70, 94, 96, 112] A later study on the basis of three radio collared leopards found that dispersal starts at an age between 15 to 18 months. But no study has been conducted how male and female leopard dispersed and what factor affect the process [116]. Much robust studies have been carried out with large sample size on African leopards to address the dispersal ecology. 35 individual leopards found that dispersal starts at age of 13.6±0.4 months. Male individual dispersed at a further distance as compared to females (11.0±2.5) while female's

dispersal distances were low and showed philopatry. Among all the collared individuals sex biased dispersal was reported, all males dispersed while all females settled near the mother home ranges [85, 91]. Dispersal distance in case in the later study was in response to mate competition while in case of females it was inversely density dependent. In nutshell, leopard's spatial ecological studies in Indian continent are based on small sample size which put constraints to draw a general conclusion and provide fine level understanding. There are some studies which are able to generate at least base line data regarding the spatial ecology of Indian leopard [46, 71, 97, 99].

Activity pattern:

After spatial ecology, activity pattern was one of the least studied subject in case of Indian leopard. Few studies have been conducted on the activity pattern of leopards in Indian subcontinent. Most of the studies of activity pattern were carried out in order to examine the inter specific interactions or to study the spatial ecology. Camera trapping and radio collaring were the methods that are used in this studies. Studies within protected areas show plasticity in the activity patterns of leopards [72, 73, 87, 91]. Leopards activity ranges from diurnal from nocturnal but major peaks were in during early morning hours or late evening hour. While studies carried out in the human dominated landscape found that leopards were dominantly nocturnal. Theory of activity patterns revolves around bottom up or top down theory. Bottom up process predicts that predator will follow the prey while top down theory predicts that predator will avoid the activity of the larger competitor. But human disturbance seems to be another major factor that could affect the activity pattern of leopards and is largely reflected in human dominated land. Day time temperature is generally important abiotic factor which affect the activity pattern of the leopards. Some studies show a decline in activity peak of leopard [11, 37]. During mid-day time when temperature is high but impact of the factor has not been quantified yet. Despite large use of camera trapping in ecology in the Indian subcontinent, only few studies quantified the activity pattern of leopard. Camera trap are affective means to study the pattern such as activity of space use in low density areas also but radio telemetry can provide the finer level information in relation to age and sex which is presently lacking in case of Indian leopard[75, 101, 107].

Behaviour:

The Indian leopard is a solitary, elusive and nocturnal Big Cat of Indian Jungle. These behaviours, combined with a natural aloof mentality and stealthy habits make it an apex predator in its habitat.

Territorial Behaviour:

Demarcate territory using scent-

- **Scent marking by both sexes-** Males mark more frequently than females.
- **Forms of marking-**

Urine marking: 2 types of urine marking were observed-

Spraying of Urine- Deposit urine and anal sac secretions. Most frequently done along used roads, trails, and game paths and at boundaries of territory. The frequency of urine spraying was relatively increased during the oestrus period.

Squatted urination- This type of urination only found in Female Indian Leopard.

Scratching: Scratched trees may serve as territorial markers. Serves as a visual and chemical signal.

Advertise through vocal calling –

- **Auditory sawing**- known as coughing or rasping. Calls may advertise territory and/or reproductive availability. Sound carries to 3 km (nearly 2 mi).

Stalking Behaviour for hunting:

The leopard can either stalk its prey over long distances, or, it can patiently wait in an ambush type position if it knows its prey is moving closer. At about 32 feet, the cat attacks. It dashes forward and uses its piercing and hooked claws to render its prey almost useless. The final deadly blow comes from the cat's sharp and strong teeth. These teeth bite directly at the nape of the prey's neck or at the throat. The final bite typically signals the end of the hunt [76, 100, 106].

Parental care:

Leopards are territorial carnivores that exhibit a polygynous mating system. Litters typically comprise one to three antiracial young that are cared for exclusively by females. Male leopards provide no direct parental care to offspring. Leopard cubs stop suckling at 3–4 months but mothers continue to provide the bulk of their food until they reach independence. Fewer than 40% of leopard cubs reach independence, with cub survival largely dependent on their (lack of) exposure to infanticidal males as well as maternal age (younger females typically make better mothers) [114]. The age that leopard cubs separate from their mothers varies markedly both within and between populations; ranging from 7 to 36 months. Females rarely resume breeding until after current offspring are independent hence, the duration of maternal care is likely to impact inter birth intervals and potentially the lifetime reproductive success of female leopards. Very few females cared for multiple litters simultaneously and litter replacement times were similar regardless of the duration of care. Extending care therefore increased the inter birth intervals of females limiting the number of litters they could produce during their lifetime [78, 88, 107].

IUCN RED LIST – Vulnerable

**It is widely distributed on the Indian subcontinent. It is threatened by illegal trade of skins and body parts, and persecution due to human-leopard conflict and retaliation for livestock depredation. That's why leopards are vulnerable in India (IUCN).

IUCN Status:

- **Vulnerable** (2015 assessment) [90]
 - Declining in large portions of their range; though widely distributed
- **Previous assessments** [16, 35, 90]
 - 2019 - Vulnerable
 - 2016 - Vulnerable
 - 2008 - Near Threatened
 - 2002 - Least Concern
 - 1990 - Threatened
 - 1988 - Threatened
 - 1986 - Vulnerable
- **Two subspecies have been recently assessed**
 - *Panthera pardus* ssp. *delacouri* — Critically Endangered [79].
 - *Panthera pardus* ssp. *kotiya* — Vulnerable [52].
 - *Panthera pardus* ssp. *melas* — Not Evaluated [4].
 - *Panthera pardus* ssp. *nimr* — Not Evaluated [58, 59].
 - *Panthera pardus* ssp. *orientalis* — Not Evaluated [44].
 - *Panthera pardus* ssp. *saxicolor* — Not Evaluated [50].

CITES Status:

- **Appendix I** [106]

Other Status:

- **India**
 - Listed under the Wildlife Protection Act of 1972; prohibits hunting and trade.
 - Adequately protected within reserves/protected areas; enforcement is adequate.
 - Less well-protected outside of reserves.
- **Afghanistan**
 - Protected Species List (2009); prohibits all hunting and trade within the country.

Global population size:

- **Estimates for subspecies currently being updated by IUCN** [54]
 - Amur leopard: approximately fewer than 300 individuals

- Fewer than 100 within their historic range in the Primary region of the Russian Far East
- **Estimates available from IUCN Cat Specialist Group [51]**
 - See website -- first table under "Status and Distribution"
- **Population updates not yet on IUCN Cat Specialist website**
 - Amur leopard, *P. p. orientalis*
 - Also see Conservation Status, below
 - North Chinese leopard, *P. p. japonensis*
 - 174-348 individuals, total population [58]
- **Population sizes difficult to quantify [113]**
 - Some past estimates considered unreliable [36]
 - 700,000+ in Africa; commonly cited, though calculation was reportedly flawed [36]
 - c. 10,000 in India; estimate likely inaccurate
 - Population estimates of endangered sub-species listed the following conservation section [102].

Population trend:

- **Decreasing in number [36]**
 - Eradicated from c. 37% of their historic African range [83]
 - Legal hunting and export permitted for 12 African countries, per the Convention for the International Trade of endangered species [36]
 - Annual quota for all countries: 2648 individuals [8]

Threats upon Leopards:

The primary threat to the leopard is human activity

Habitat fragmentation, reduced prey base, and human-wildlife conflict have greatly reduced this species' population throughout most of their range. Although they are widely distributed across Africa and Asia, due to habitat fragmentation and loss, their range has reduced by 31 percent worldwide in the past three generations (about 22 years) [6]. The commercialized bush meat trade has caused a collapse of prey populations across large parts of savanna Africa — estimated an average of 59 percent decline in prey populations across 78 protected areas [82, 109, 113].

Leopards can be a nuisance to locals

When brought into close contact with human settlements, they may prey on livestock. Pastoralists will retaliate and kill the big cats in retribution or will attempt to exterminate them in order to prevent livestock killings [21, 63].

The leopard's coat does not belong on humans

These big cats have long been hunted for their soft fur — used to make coats and ceremonial robes — as well as for their claws, whiskers, and tails, which are popular as fetishes [5, 51].

Human-Leopard Conflict

Leopard is one of the felids which is severely involved in conflict with humans.

Due to behavioural and dietary flexibility leopards can persist in human dominated landscape at fairly high densities [3, 91, 67]. Different types of studies which were related to leopard-human conflict and talk about patterns of human-leopard conflict, factors affecting the conflict and kill sites and spatial risk modelling by leopards and also on human perception towards leopards. Among later cited studies 55% were carried out in the multispecies assemblage while 45% were carried out exclusively on Indian leopard. Most of the studies used secondary data to assess the pattern of human leopard conflict, secondary data and field observation studies where data were procured from forest department that used for characterizing kill sites and secondary data [57, 77]. Very few studies have been conducted on regional or country scale in comparison to site specific studies. Most of the studies found that leopards predate upon livestock of medium weight such as cattle calves, goat, sheep and dogs. Preference for this weight range of leopards is also very much reflected in diet in natural areas. Not only scale of conflict but the timings of conflict also vary in between the sites [89]. Some studies reported that livestock depredation occurs during night time dominantly, while other studies reported mid-day and night and afternoon and evening as major peak times of depredation [81]. Distance from protected area and grazing inside the protected area reflected as major factors affecting the livestock depredation. Generally conflict occurs in surrounding areas that indicates involvement of more complex reasons and species ecology has a larger role to determine the cause of livestock predation by leopards [42, 88]. Livestock predation also depends very much on the husbandry practices. Open grazing of cattle inside the protected areas results in more frequent encounters, hence greater predation of livestock than in case of stall feeding where livestock are guarded in the physical structure. Livestock predation by Indian leopards in the Indian subcontinent seems to be a complex issue where specificity and other ecological condition effect the level of depredation [86, 108, 112].

Human-Leopard conflict in West Bengal:

“Change in land use pattern especially for enhanced tea plantation has affected leopards population extremely Encroachment of forest land has brought leopards close to human habitats. Between April 2001 and March 2008 [25, 74, 2]. Most of the leopard attacks have taken place in tea gardens in Western chief places for conflicts as leopards can prey upon cattle reared by tea garden workers”. Leopards consume boars, deer, birds and rodents mostly. They enter into villages to attack the domestic animals like cow, goat, dogs, cats etc. Sometime they can fulfil their needs and sometimes they get injured by humans. Leopards are cunning in nature that's why chemical metabolization is rarely is successful for immobilizing them [2].

Ecological Significance:

Indian leopard play a pivotal role in maintaining ecological balance and biodiversity in their habitats highlighting the importance of their conservation of the overall health of the ecosystems [44, 100].

Apex predators: Leopards often occupy the top of the food chain in their habitats, regulating prey population different types of ungulates, wild boar and smaller mammals. By controlling herbivore numbers, they indirectly influence vegetation dynamics and biodiversity [104, 111, 115].

Ecosystem: presence of leopard helps to maintain the balance of species diversity, natural interaction of different organisms and ecosystem stability (prevent certain herbivore population from overgrazing, which can lead to habitat degradation).

Indicator species: They serves as indicators of ecosystem health. Their distribution and abundance reflect the health and integrity of their habitats, making them important for monitoring ecosystem changes and identifying conservation priorities.

Seed dispersal: Like other carnivores, leopard contribute to seed dispersal by consuming fruits and seeds along with their prey. This behaviour aids in the regeneration of plant species and support forest health [100, 105].

Culture and economic health: In regions where leopards are revered culturally or attract ecotourism, they contribute to local economics and conservation efforts through tourism revenue and awareness [98, 105, 110].

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