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# Harmony and Discord: Unravelling Spatial Distribution and Seasonal Dynamics of Human-bear (*Ursus thibetanus*) Conflict in Fambonglho Wildlife Sanctuary, Sikkim Himalaya

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## ABSTRACT

**Background:** The Asiatic black bear (*Ursus thibetanus*) is a federally protected species facing conservation concerns due to habitat depletion, food and environment driven altitude migration and its conflicting domain with humans. This study, conducted in the Fambonglho Wildlife Sanctuary, Sikkim Himalaya, emphasizes the need to understand seasonal variations in bear ecology and human interactions.

**Methods:** Field surveys for four seasons viz. Spring (April-June), Summer (July-September), Autumn (October-December) and Winter (January-March) and interviews in the fringe villages (2021-2023), human-bear conflict secondary data (2019-2022) and camera trap data (2016-2017) were analysed using the GIS and statistical tools, revealing specific spatial distribution and seasonal patterns of human-bear conflicts.

**Result:** Bears in Sikkim's Fambonglho Wildlife Sanctuary, flourish mostly at 2200-2400 meter above mean sea level, in mixed temperate forests, exhibits bimodal activity and non-hibernating behaviour. Conflicts peak in summer and autumn, with 98.4% crop raiding on maize and livestock depredation peaking in autumn ($p = <0.0001$). Settlement proximity peaks in June-September (41%) and decreases in winter (59.9%). Locals rank bears as the primary threat (40.77%, rank 1). Understanding these dynamics informs conservation strategies for harmonious coexistence in the fragile Himalayan ecosystem.


**Key words:** Asiatic black bear, Camera trap, Human-bear conflict, Spatial distribution, *Ursus thibetanus*,

## INTRODUCTION

The Asiatic black bear (*Ursus thibetanus*), or Himalayan black bear (hereafter referred to simply as bear), is federally protected and ecologically vital across its distribution from Southeast Iran through Afghanistan and Pakistan, eastward along the lower foothills of the Himalayas in India, Nepal, Bhutan, China, Southern Russian Far East and North and South Korea (Servheen *et al*., 1999). Altitudinal migration, driven by food availability and environmental factors, remains a crucial aspect studied globally but lacks specific insights from Sikkim. Previous works underscore elevation's role in habitat selection by bear (Kichloo and Sharma 2021), while Kumar and Basnet (2019) provide insights into habitat use and elevation preference in Sikkim. The Fambonglho Wildlife Sanctuary (FWLS) in Sikkim Himalaya serves as a unique study area due to its diverse elevational gradients (1500-2750 meter above mean sea level). Observations in FWLS prompt questions about the drivers behind elevation shifts, necessitating a comprehensive investigation. Human-wildlife conflicts surge due to expanding populations and land use changes, impacting agro-pastoral economies (Bussa 2023; Lamarque *et al*.2009). Livestock depredation poses significant livelihood threats (Ogada *et al*., 2003), with human activities affecting bear behaviour and escalating conflicts (Ji *et al*., 2022). Conflicts involve bear attacks, livestock predation, crop raids and human casualties (Charoo *et al*., 2009; Mir *et al*., 2023). Farmers' perceptions differ from other stakeholders (Kumar *et al*. 2017; Kellert, 1990), with human life threats predominantly linked only to bear conflicts in Sikkim and Darjeeling with retaliatory actions being conspicuously absent (Rai *et al*. 2014). Nevertheless, conservation programs involving locals cultivate unique environmental values, enhancing their motivational impact in conventional science frameworks (Abebe, 2020). This research unveils subtle stakeholder differences, offering critical insights into conflict resolution in specific ecological landscapes. In FWLS, the study analyses seasonal spatial distribution, elevation use and

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human-bear conflicts, enhancing global bear ecology understanding and contributing significant findings to address dynamic conservation challenges.

## MATERIALS AND METHODS

### Study area

Fambonglho Wildlife Sanctuary (FWLS) in Sikkim, India, established in 1984, spans 51.76 sq. km (Fig: 1) within the Central Himalayas bio-geographical zone 2C (Rodgers and Panwar, 1988), located between 27° 10′ to 27° 23′ N, 88° 29′ to 88° 35′ E, at 1500 to 2750 meter above mean sea level. With 3000-4000 mm annual rainfall, it serves as a crucial water source. Encompassing major forest types like East Himalayan sub-tropical wet hill (Type 8B/C1) and East Himalayan wet temperate forests (Type 11B/C1), it features species such as *Alnus spp., Schima wallichii,* Oaks, Magnolias and Rhododendrons. Home to scheduled species like Leopards, Bears, Red pandas and Binturongs, the sanctuary supports villages through 10 Eco-Development Committees. The economy, dependent on agriculture, cardamom cultivation and government services, is vital for Nepalese, Bhutia and Lepcha communities relying heavily on forest resources like Non-Timber Forest Products (NTFPs), fodder, firewood, water and tourism for their livelihoods.

### Sampling and survey

Conflict history around FWLS was evaluated during a meeting with village elders, Eco-Development Committees and staff from the Forest and Environment Department, Government of Sikkim. Additionally, three years of secondary data (2019-2021) on Human-wildlife conflicts were collected from the Forest and Environment Department. The study used ArcGIS ver.10.7.1 Desktop to divide the study area into 3 km$^2$ grids, a sign survey conducted along natural trails covering each grid by a team comprising at least a local shepherd, a Forest Guard and a conservation expert, walked for four seasons *viz.,* Spring (April-June), Summer (July-September), Autumn (October-December) and Winter (January-March) and recorded signs such as bite marks, broken stems and branches, dens, rock disturbances, tracks, footprints, claw marks, soil diggings, hair, scats and food remains (Steinmetz and Garshelis 2010; Kabir *et al*. 2017; Hameed *et al*. 2020; Nawaz *et al*. 2021) and coordinates recorded using Garmin Montana 650 GPS. Categorization by age of bear signs followed Scotson (2010); Fresh (1-3 months), Recent (3-12 months), Old (1-2 years) and Very Old (>2 years).

A survey of 117 people in FWLS peripheral villages from February 2022 to March 2023 was conducted using qualitative and quantitative methods including participatory observation, group discussions and structured/ unstructured interviews. A similar investigation (Goursi *et al*. 2021) demonstrated informativeness. Snowball sampling was also used very carefully to avoid biases. Demographic profiles, human-bear conflict, attitudes towards bear conservation, disturbance patterns and crop/livestock damages for the past three years were studied following Farhadinia *et al*. (2017). IBM SPSS Statistics 2023 tested

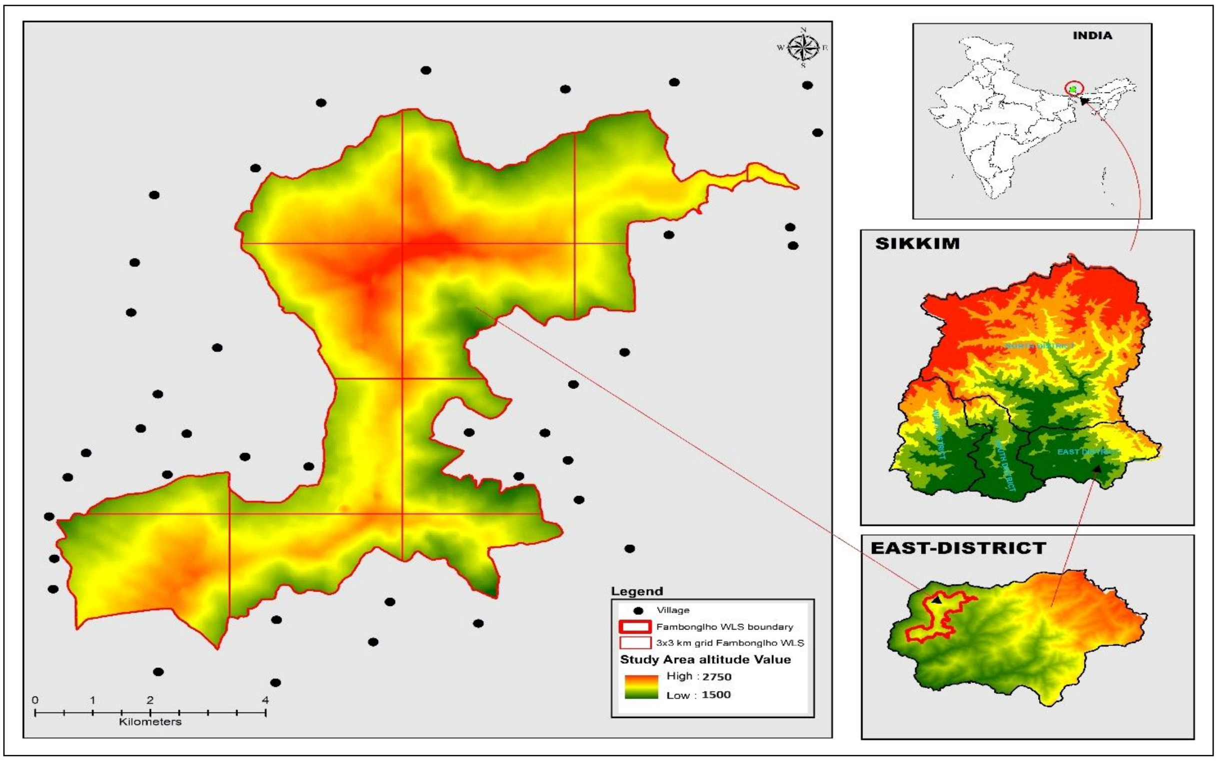


**Fig 1:** Study Area Map.

the following hypotheses about crop raiding and livestock depredation during different seasons using Chi-Square Goodness of Fit Tests.

**Null Hypothesis 1 (H01)**

There is no significant difference in the frequency of bear conflicts due to crop raiding among different seasons.

**Alternative Hypothesis 1 (H1)**

The frequency of bear conflicts due to crop raiding is significantly higher in one particular season compared to others.

**Null Hypothesis 2 (H02)**

There is no significant difference in the frequency of bear conflicts due to livestock depredation among different seasons.

**Alternative Hypothesis 2 (H2)**

The frequency of bear conflicts due to livestock depredation is significantly higher in one particular season compared to other seasons.

Interviewees ranked wildlife threats on an ordinal scale of threat rank (1 to 5) based on participant's response and then calculated the percentages to determine the ranking of different animals according to their perceived damage causing potential in relation to livestock depredation, crop damage and threat to life. Altogether, the interview lasted for 30-40 minutes, in the local Nepali dialect, assured participants of no special recompense for losses or persecution, emphasizing independent data collection.

**Camera trapping**

Secondary camera trap data (mostly Cuddeback C1) from Sikkim's Forest and Environment Department covered 14 locations in the study area where animal movement is expected. Collected between November 2016 and March 2017, traps were 15-30 cm above ground, fastened to trees or rocks 3-5 meters from trails. Various configurations, including head-on, oblique and side view, were employed to capture photos at different body angles. Photographs were carefully examined for identification at Wildlife Institute of India, Dehradun.

**Human-Bear conflict vulnerability mapping**

ArcGIS ver.10.7.1 Desktop (ESRI, 2019), utilized camera trap data to identify villages prone to bear intrusion. Orthorectified with ASTER DEM, three concentric buffers using the below formula, were drawn around bear observation points.

$$r = \sqrt{(A / \pi)} \qquad \text{(i)}$$

$$A = \pi * r^{\wedge 2} \qquad \text{(ii)}$$

Where
A = Area
r = Radius.

The 3 km² buffer represented the smallest recorded home range, the 28 km² buffer reflected the largest and an intermediate buffer (12.5 km²) captured the average home range of bear based on Hazumi and Maruyama (1986); Charoo *et al*. (2009); Sunar *et al*. (2012). Villages within the innermost buffer were deemed highly vulnerable, those within the middle buffer moderately vulnerable and those beyond least vulnerable.

**Scat analysis**

The Bear's scat analysis was primarily visual, identified bear scats easily due to their unique scat pattern which no other carnivore produces. Collected scats were placed in Ziploc bags for additional identification (Ali *et al*., 2017), prioritizing fresh samples with minimal environmental exposure. Air-drying scat samples is a preferred method (Laguardia *et al*., 2015; Aziz *et al*., 2017), as it maintains their integrity for morphological analysis. Sieves of varying mesh sizes separated scat components (Yamazaki *et al*., 2012), validated by wildlife biologists for plant and animal identification to minimize misinterpretations as Elbroch *et al*. (2011) also emphasizes the importance of expert knowledge in conservation research.

All aforementioned activities were carried out under the supervision of Computer Application Department, Sikkim Manipal Institute of Technology, Sikkim Manipal University, Sikkim, India, from the year 2021 to 2024.

## RESULTS AND DISCUSSION

**Sign survey**

A study found 195 bear signs in FWLS at altitudes ranging from 1779 to 2654 meter above mean sea level, including feeding remains, tracks, scats, footprints and claw markings. Fresh signs constituted 62.37%, recent 25.26%, while old signs accounted for 7.73% and very old 4.64%. Signs concentrated mostly in temperate broad-leaved forests at 2200-2400 meter above mean sea level (64.7%), followed by 2400 -2600 meter above mean sea level (26.5%) and 2000-2200 meter above mean sea level (8.80%), emphasizing the conservation importance of mid-elevation zones, consistent with Li *et al*. (2015). Resting sites and claw marks were predominantly identified on trees such as *Symplocos lucida*, *Symplocos glomerata*, *Eurya acuminata*, *Quercus lamellose* and *Lithocarpus pachyphyllus.* Dens were observed in *Quercus lamellose*, *Lithocarpus pachyphyllus*, *Nyssa javanica*, *Castanopsis hystrix*, *Elaeocarpus lanceifolius* and caves. Claw marks were often on trees associated with the *Cissus elongata* climber. Even patches of *Cryptomeria japonica* were found to host bear signs, expanding our understanding of bear habitats. Bears extensively fed on fruits from various plants, including *Holboellia latifolia*, *Beischimedia roxburgii, Michilus spp., Alangium salviifolium, Rubus spp., Symplocus spp., Viburnum spp.,* Chestnut and Oaks. Specific vegetation types and altitudinal distribution underscored the adaptability and preference of bears for diverse ecological niches. Claw marks on trees with the *Cissus elongata* climber, *Holboellia latifolia* and Pyrularia *edulis* highlighted their habitat significance. Bear trails in bamboo thickets and oak forests near water sources or feeding areas indicate vital movement corridors, aligning with Gautam and Pradhan (2020). This study highlights habitat improvement through planting specific species is crucial.

The study challenged traditional beliefs on FWLS bears' hibernation, proposing a modified winter dormancy influenced by milder winters in Sikkim. Similar observations were made in Himachal Pradesh (Saberwal 1989; Schaller 1969). Spatial distribution indicated dynamic seasonal shifts (Fig 2), with spring and summer foraging below ridges, aligning with Kumar and Basnet (2019). Autumn dispersion across altitudes was influenced by oak acorns and denning preparation (Garshelis and Pelton, 1981).

Only 11 signs in winter point towards bears' reduced activity, while fresh signs, dens and rare depredation of livestock show a propensity for winter denning, with opportunistic foraging. The study found Millet, *Cissus elongata, Arisaema spp.* and Oak seeds in the scat during winter and spring and maize crops in the scat during summer and early autumn. Trails, feeding remains and pug marks in maize fields underscore their reliance on anthropogenic crops.

**Human-Bear conflict interview**

The study, involving 117 participants, identified distinct seasonal conflict patterns. Null hypothesis 1 (H01) rejected in favour of the alternate hypothesis (H1); the frequency of bear conflicts due to crop raiding is significantly higher in one particular season compared to others. Crop raiding conflict frequencies show a significant spike in summer with 67 reported incidents, surpassing the expected 39 (Table 1a and 1b). During autumn, only 5 conflicts were reported, with no winter reports. Crop damage frequencies varied, with maize (98.3%), squash guard (35.9%), tubers (16.2%), vegetables (40.2%), paddy (10.3%) and fruits (17.1%) (Fig 3). Crop-related conflicts peak in summer, potentially driven by crop ripening, altered dietary needs, or behavioural adaptations. Bears primarily damaged maize crops in summer, targeting squash, tubers and paddy in autumn and winter. Fruits and vegetables were also impacted in both the seasons. Given the central role of Maize crop in conflicts, alternating crops in consultation with relevant agencies and proper fencing, may reduce substantial crop damages from summer through early autumn.

Similarly, Null hypothesis 2 (H02) is also rejected in favour of alternate hypothesis (H2); the frequency of bear conflicts due to livestock depredation is significantly higher in one particular season compared to other seasons. Autumn sees a surge in livestock depredation, reporting 57 conflicts compared to the expected 29.3, while winter records only 5 incidents, with a chi-square value of 48.026 (Table 1c and 1d). The significant difference ($p<0.001$) between observed and expected conflict rates underscores the correlation between crop raiding and livestock depredation, influenced by seasonal shifts in food availability. Over three years, livestock depredation data (Fig 4) reveals impacts on Cattle (14 No., 12 incidences), Goats (71 No., 31 incidences), Chicken (129 No., 8 incidences), Honeybee hives (2 No., 2 incidences) and an unusual Dog case (1 No., 1 incidence). Cattle and Goats suffer the most, particularly in autumn, posing economic challenges. Autumn incidents peak at night, aligning with Mir *et al*. (2015) findings. Winter signifies a more harmonious coexistence, with rare direct human-bear conflicts (n=5), emphasizing the need for understanding interactions. Settlement proximity peaks in June-September

**Table 1:** Chi-square statistics for crops and livestock depredation by bear.

**a) Chi-square test for goodness-of-fit**

| | Seasons when most crop raid occur | | |
|---|---|---|---|
| | Observed N | Expected N | Residual |
| Spring | 45 | 39.0 | 6.0 |
| Summer | 67 | 39.0 | 28.0 |
| Autumn | 5 | 39.0 | -34.0 |
| Total | 117 | | |

**b) Chi-square test statistics**

| | Seasons when most crop raid occur |
|---|---|
| Chi-Square | 50.667 |
| df | 2 |
| Asymp. Sig.. | 000* |

There is not a single cell (0.0%) with expected frequencies < 5. 39.0 is the minimum expected cell frequency.

**c) Chi-square test for goodness-of-fit**

| | Seasons when livestock mostly depredated | | |
|---|---|---|---|
| | Observed N | Expected N | Residual |
| Winter | 5 | 29.3 | -24.3 |
| Spring | 32 | 29.3 | 2.8 |
| Summer | 23 | 29.3 | -6.3 |
| Autumn | 57 | 29.3 | 27.8 |
| Total | 117 | | |

**d) Chi-square test statistics**

| | Seasons when livestock mostly depredated |
|---|---|
| Chi-Square | 48.026 |
| df | 3 |
| Asymp. Sig.. | 000* |

There is not a single cell (0.0%) with expected frequencies < 5. 29.3 is the minimum expected cell frequency.

Df- Degree of freedom, Asymp. Sig.- Asymptotic significance, *Significant at P≤0.05; NS- Non-significant at P>0.05

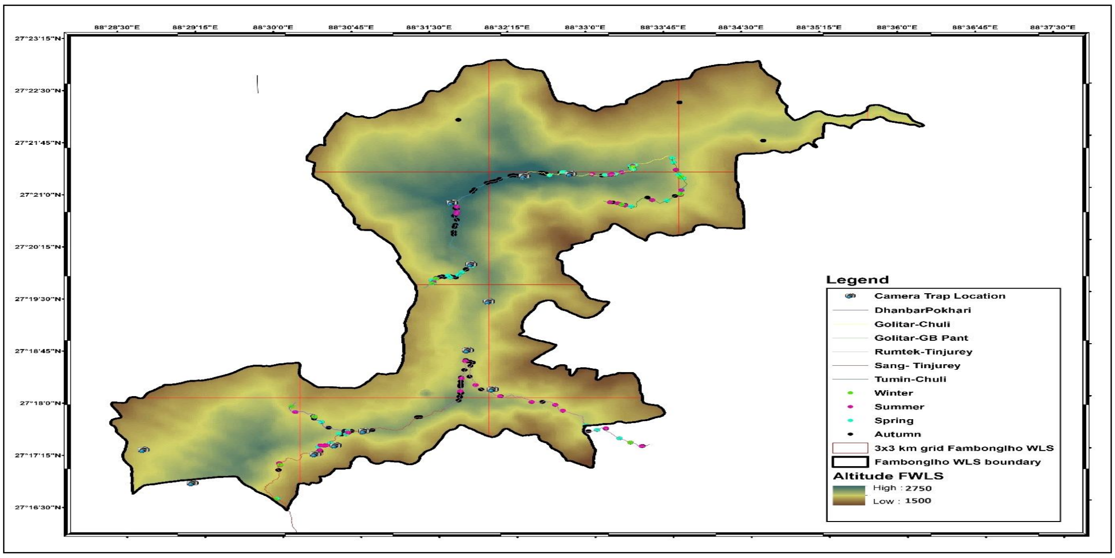


**Fig 2:** Seasonal spatial distribution and elevation use by bear in the FWLS.

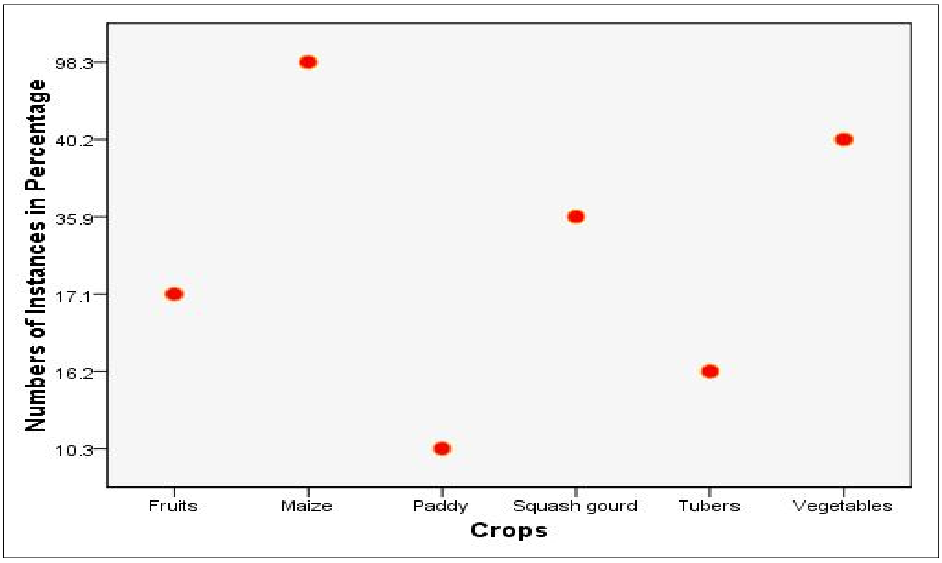


**Fig 3:** Crop depredation in the fringe villages of FWLS.

(41%) and decreases in winter (59.9%), correlating with reduced bear activity. Given that most livestock depredation occurs in autumn; robust sheds would significantly protect them.

Local communities (n=117) identify black bears as the primary threat to livestock and agriculture (40.77%, rank 1), consistent with Goursi *et al*. (2021) and Ali *et al*. (2022). Mitigation strategies, including secure enclosures, noise deterrents and awareness campaigns, have proven effective (Mishra *et al*., 2006; Treves *et al*., 2020). Conch playing also deters bears in the study area. Despite compensation challenges, locals display limited retaliatory tendencies like Rai *et al*. (2024).

### Camera trapping study

In FWLS, 14 camera traps captured 158 images over 459 days or nights, recording various wildlife species. The mean photo capture rate for the eight bear events was 3.35, with a standard error of 1.98 (Lepcha *et al*., 2017). Most signs identified at an altitude of 2200-2400 m and confirm bimodal activity even in winter peaking after sunset and during night, discerning the hibernation theory.

### Human-Bear conflict vulnerability mapping

Human-bear conflict mapping reveals three distinct vulnerability zones, with villages experiencing more conflicts falling within the highly vulnerable zone, of 3 $Km^2$ buffer, the smallest recorded home range of the bear validating the model (Table 2 and Fig: 5). Additionally, some villages in the moderately vulnerable zone reported confirmed bear sightings due to their proximity to forests. Mapping conflict zones in fringe villages aids in formulating targeted mitigation strategies in FWLS.

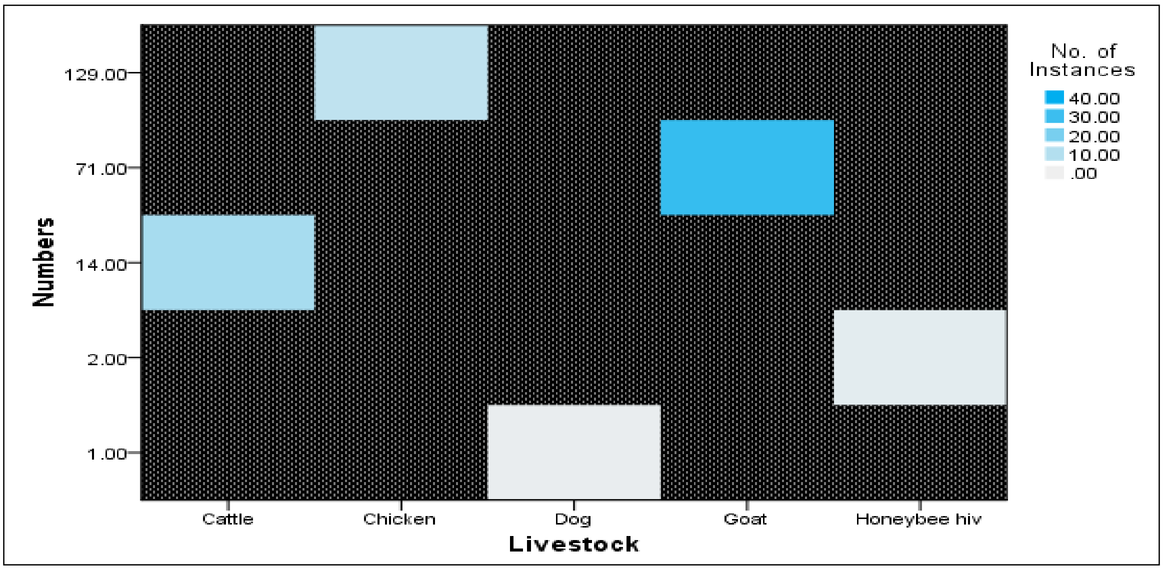


**Fig 4:** Livestock depredation in fringe villages of FWLS.

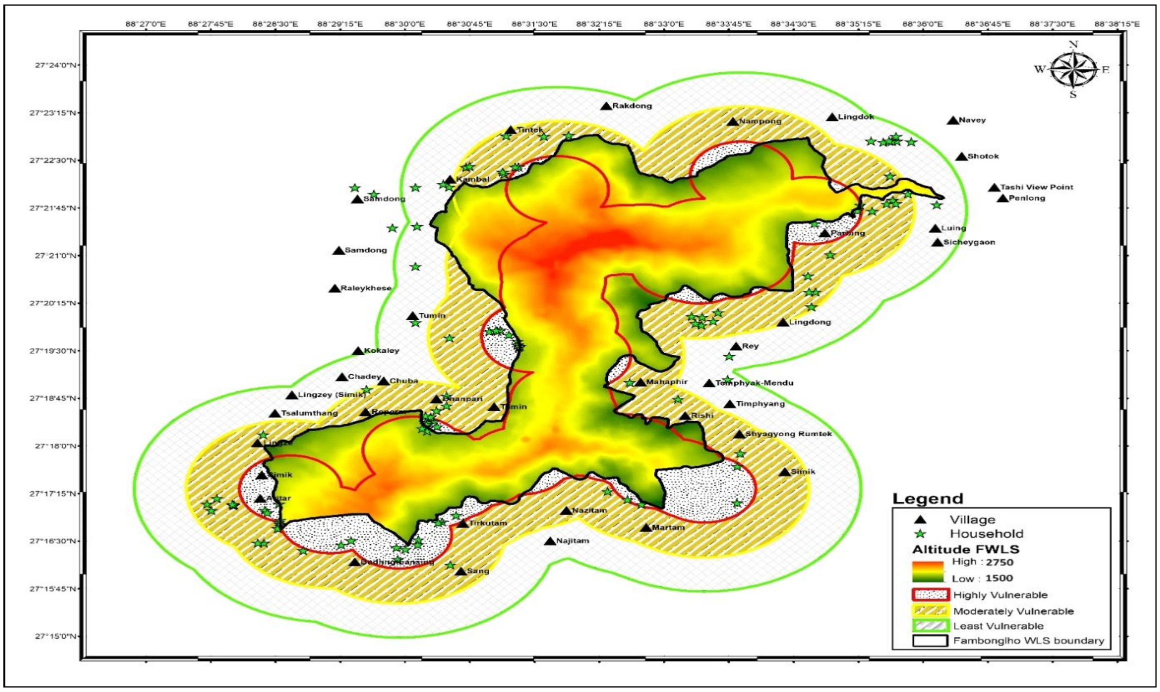


**Fig 5:** Human-bear conflict village vulnerability map

**Table 2:** Human-bear conflict vulnerability of fringe villages of FWLS.

| Highly vulnerable village | Moderately vulnerable village | Least vulnerable village |
|---|---|---|
| (Within 3 km$^2$ buffer) | (Within 3 km$^2$-12.5 km$^2$ buffer) | (Within 12.5 km$^2$-28 km$^2$ buffer) |
| Aritar, Simik, Dhanbari, Thangsing, Namrang, U. Tintek, Nampong-Chader Gumpa, Perbing, Tirkutam, Navey, Beng, Byeng, Phegyang, Patieum, Lingtam, Chinzey, Shyanyang-Rumtek, Sama-Sivik, Chongrang. | Nazitam, Martam, Sang, Lingze, Roperm, Tumin, Tintek, Nampong, Mahabir, Rishi, Shyanyang-Rumtek, Simik, Tirkutam, Dhanbari, Rey. | Tsalamthang, Lingzey-Simik, Chadey, Chuba, Kambal, Rakdong, Lingdok, Luing, Sichegaon, Lingdong, Temphyang-Mendu, Timphyang, Nazitam. |

## CONCLUSION

This multifaceted study highlighted the critical need for holistic conservation strategies that balances bear ecology and socio-economic needs of communities in the Fambonglho Wildlife Sanctuary, Sikkim Himalaya. The observations emphasize mid-elevation zones, diverse habitats and seasonal and temporal patterns of bear distribution, offering insights into human-bear conflict dynamics. The study challenges traditional hibernation beliefs, suggesting bimodal bear activity and modified winter dormancy. Vulnerability mapping identifies high-conflict zones, aiding targeted mitigation efforts. Mitigation strategies like crop rotation, fencing and robust sheds are recommended. Collaborative initiatives involving local communities, agencies and conservationists are recommended for long-term bear conservation and conflict reduction in FWLS. This knowledge aids in crafting and executing conservation initiatives, promoting sustainable and harmonious coexistence within the landscape.

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**Conflict of interest**

All authors declare that they have no conflict of interest.

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