



Can safer livelihood practices strengthen human-tiger coexistence in Sundarban Biosphere Reserve, India?

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ABSTRACT

Human-wildlife negative interaction is a serious livelihood and conservation concern in areas that are densely populated as well as rich in biodiversity. This study analyses the impacts of safer and energy-efficient livelihood practices - goat and poultry rearing and improved cooking stoves (ICS) - in reducing forest dependency of local communities and strengthening human-tiger coexistence across three villages within Sundarban Biosphere Reserve, India. Forest visitation, fuelwood harvesting and income for pre- & post-intervention durations (2012–2018 & 2019–2025, respectively) were assessed through key-informant interview survey with 30% of beneficiaries. Forest visitation for fuelwood harvesting and fuelwood harvesting reduced by about 70% ($p < 0.001$) and 30% ($p < 0.001$) per month, respectively. Average household income increased by 20–25% per month ($p < 0.001$). The estimated average annual human-tiger negative interactions in the three project villages declined by 46%. The results indicate that combining locally appropriate safer and energy-efficient livelihood practices improves safety and financial status of vulnerable forest-dependent communities. In the context of the Sundarban Biosphere Reserve, which is also a Tiger Reserve and a National Park, we discuss how such community-based initiatives contribute to garnering public support towards strengthening social capacity for human-tiger coexistence.

Societal impacts

Human-wildlife negative interactions represent a persistent societal challenge in regions where ecological significance overlaps with poverty and livelihood insecurity [1]. The Sundarban Biosphere Reserve - a globally important mangrove ecosystem at the Ganges-Brahmaputra delta - supports both the world's only mangrove-adapted tiger population and millions of people dependent on forest resources for survival [2]. The Sundarban ecosystem offers essential services ranging from coastal protection and fisheries to carbon sequestration services [3].

In this context, conservation is closely linked to livelihood security. A combination of high human population density, erosion and salinization processes causing land loss, have led to people's high dependency on forests [4]. Activities like harvesting fish, crab, honey and fuelwood entail regular entry into the forests and creeks. The forest-dependent households face a consistent risk of accidental tiger attacks [5]. Over the years, the adverse interactions between humans and tigers in the

Sundarban have caused significant human casualties. In addition, there are significant social and economic impacts on households [6]. The situation suggests that in a complex socio-ecological ecosystem like Sundarban, a protection-only approach is insufficient [7]. The local people's dependence on forest resources is a key driver of human-tiger negative interactions, with entry in forests for resource harvesting being one of the most important cause of human injuries and deaths in Sundarban [6]. Often, following an accidental attack on resource harvester by tiger inside forest or an ingress by tiger into village, strong public reaction is observed in the form of mass agitation, blockade of forest department offices and/or operations, and occasionally, physical assault by violent mob towards front-line officers and staff. Such high-risk visitation can potentially be reduced with locally appropriate livelihood diversification and household-level interventions focusing on safer and energy efficient practices.

Research about human-carnivore tolerance shows that an improvement in economic well-being significantly changes people's perception

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of large carnivores. Households with economic security are more likely to perceive wildlife as an acceptable risk and not as an existential threat. This aligns with the risk perception accepted hazard model [8,9]. In areas where conservation success is reliant on community support, community willingness to share space with wildlife is essential.

The societal value of this work lies in its non-compensatory approach. The main emphasis is on avoiding negative interactions rather than compensating after loss. Additionally, poultry and goat rearing provide income as well as nutritional value (protein) at the household level.

This study contributes to the existing literature in two unique ways. In contrast to the majority of livelihood-based conservation interventions that address either income or energy access in isolation, this study analyses a dual-pathway model that combines supplementary livestock-based livelihoods with improved cooking technology and generates evidence on their combined effect on reduced dependency on forests. Second, the study uses a socially grounded assessment of coexistence through monitoring human-tiger negative interactions and community behavioural indicators, mainly participation in active conflict mitigation and the trend in retaliatory aggression.

Methodology

Study area

The study was conducted across three villages: Deulbari (22°00'14.0"N; 88°35'53.2"E), Maipith (21°55'12.4"N; 88°32'34.7"E), and Binodpur (21°54'26.5"N; 88°32'01.7"E), located within 1 km from forest boundary in the Sundarban Biosphere Reserve, Kultali Block, South 24 Parganas District, West Bengal, India (Fig. 1). The main

livelihood activities of the villagers include fishing and harvesting of other forest-based resources, such as honey, crab, fuelwood and prawnseed. The forest-based livelihoods of Sundarban are significant not just economically, but environmentally and socio-culturally. The project villages have developed occupational identities over centuries as reflected in the nomenclature of the hamlets. Particularly, *Shikari Para* (*shikari* – hunter; *para* - locality) and *Naiyya Para* (*naiyya* - boat) of Deulbari show that forest and river-based livelihoods are not merely theoretical, but deeply embedded in daily practice, and constitute the identity of these communities. The economic activities that are not just for survival but which are integrally embedded in the delta community's seasonal calendars are fisheries, harvesting of honey, crab and fuelwood [10].

Settling of these villages can be traced back to the reclamation of Sundarban during colonial period when mangrove forests were cleared and embankments constructed for agriculture. Migrants came to this area and settled here forming permanent settlements. Forest-based activities of these communities are also associated with a common culture. For instance, worship of *Bonbibi* (local forest deity) by both Hindus and Muslims has emerged as a ritual for protection from tigers while harvesting forest-based resources. This indicates a strong cultural and spiritual bond between the local people and the mangrove forest.

Interventions

To address the issue of forest visitation by local people for resource harvesting, two major interventions were piloted – poultry and goat, and improved cook stove (ICS). Forest-dependent families were supported for rearing backyard poultry (161 beneficiary households) and goats (289 beneficiary households) as safer livelihood options. Raised

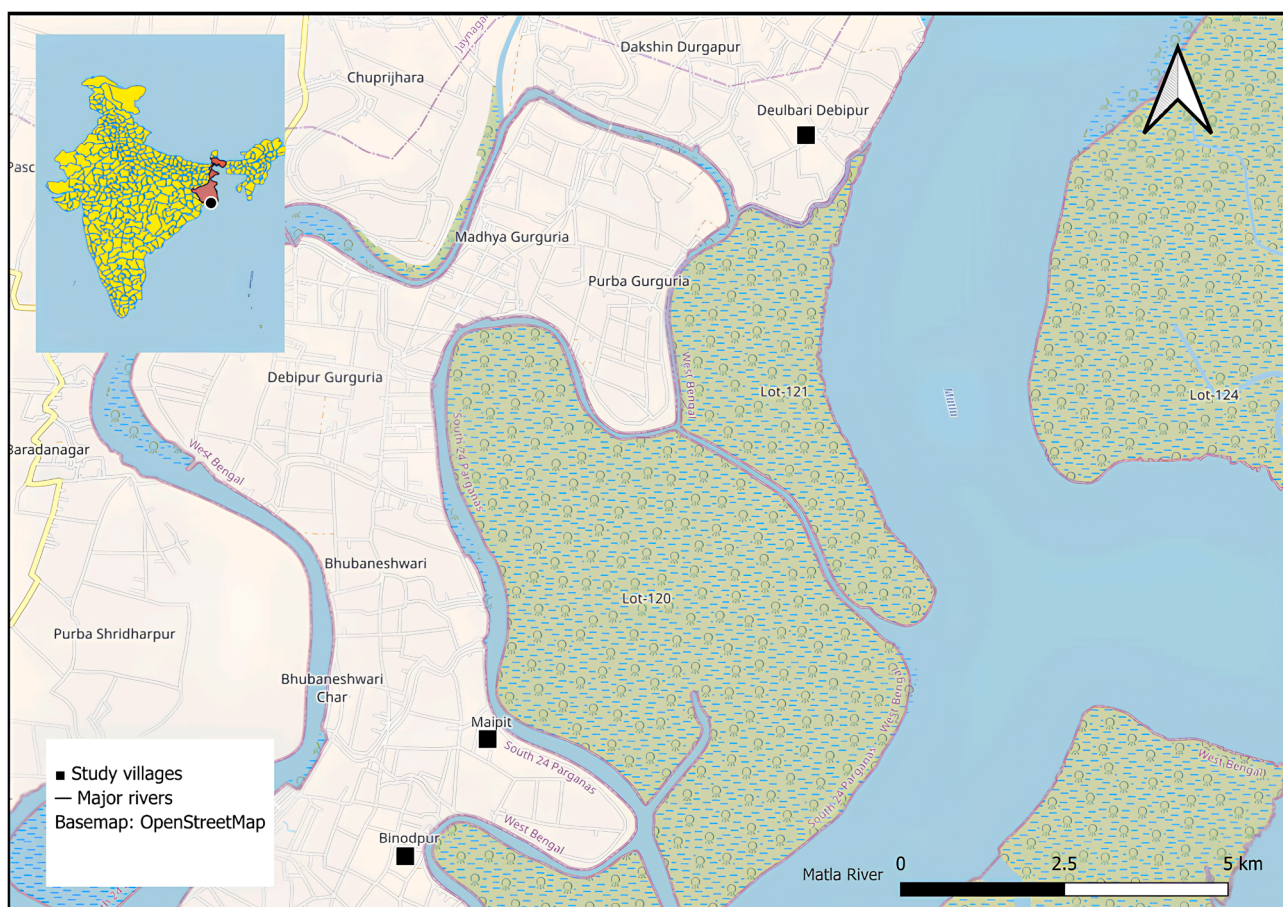


Fig. 1. Study area and sample villages, Indian Sundarbans, West Bengal, India, with Kultali Block inset. Source: Google Earth (2025); authors' QGIS map (2025).

platform housing for livestock was provided to all beneficiaries. This housing was constructed from locally available materials and was mainly designed to protect livestock from attacks by carnivores as well as cyclones and flooding. Backyard poultry and goat rearing are conducted within or immediately adjacent to the household, fundamentally altering the spatial relationship between beneficiaries and tiger habitat. Before the distribution of livestock, training on animal management, feed preparation, and disease control was provided to each beneficiary. The training was followed by a series of refresher trainings with hand-holding. Beneficiaries were trained to install, operate and maintain ICS that incorporate advanced combustion and chimney systems to reduce wood use as well as smoke exposure. Beneficiaries participated in practical sessions where they constructed stoves with clay.

Beneficiary selection

The criteria for selecting beneficiaries included low household income, primary dependence on forest-based occupations, and absence of formal employment, such as government or private sector jobs. Households with higher incomes or non-forest-based livelihoods were not considered. Selection was carried out through socio-economic surveys, following which the Forest Department reviewed the list of beneficiaries. All selected households provided Free, Prior and Informed Consent (FPIC) in accordance with the Environmental and Social Management Safeguards (ESMS) of the IUCN-ITHC project. In total, 450 households participated in the livelihood intervention and 825 households in the cookstove intervention across the three villages, with proportional distribution across villages. Beneficiaries belonged to an adult age group ranging from 18 to 80 years, with a median age of 32 years, and all beneficiaries were women. To monitor livestock survival, income generation, and adoption challenges, monitoring visits were done on a bi-weekly basis.

Survey and data collection

Baseline and follow-up household surveys were conducted using a structured questionnaire. The same households were interviewed both before and after the interventions, about a year apart. The survey covered the following aspects: demographics and family size; primary and secondary livelihood sources; monthly household income (in Indian Rupees, ₹); forest visitation frequency (visits per month); fuelwood consumption (kg per day); beneficiary perception and satisfaction with interventions. Responses and tracking of outcomes were verified through 25 Focus Group Discussions (FGDs) and field monitoring. FGDs were conducted with forest-dependent community members to document livelihood preferences and to obtain informed consent for the adoption of ICS.

For livelihood monitoring, project staff collected household income data at six-month intervals, and records were maintained for number of goat kids born and livestock survival. For ICS beneficiaries, monitoring focused on changes in fuelwood use, including firewood consumed and the plant species used for cooking. All livelihood and ICS beneficiaries were monitored following the distribution of livestock and installation of cookstoves respectively. Approximately 30% of beneficiaries were subsequently surveyed to assess both interventions. The survey questionnaires are provided as [Supplementary materials 1 and 2](#).

The interventions explained in this paper were presented as voluntary options and not as substitutes for current practices. Following a group discussion in the village, each household chose their preferred livelihood intervention and provided written Free, Prior and Informed Consent (FPIC). As of now, 95.11% of livelihood beneficiaries continue to engage in safer livelihood activities piloted through the project.

Data analysis

All data were compiled in Microsoft Excel. For each indicator,

descriptive statistics were generated, which included mean, median, standard deviation, and range. Pre- and post-intervention values were compared for number of forest visits per month, fuel wood consumption and household income. Box-and-whisker plots were prepared to show changes across three villages and intervention types.

Limitations

The project interventions were implemented as a pilot across three villages in Kultali Block. The interventions were aimed at benefiting entire households in terms of reducing dependency on forests and forest visitation. However, a higher level of engagement from women was observed as primary beneficiaries rather than from men. The household income and forest visitation data are self-reported and consequently, they are liable to recall and social desirability biases.

Results and implications

The average number of visits to the forest decreased from 19.50 to 5.58 per month, a reduction by about 70%, corresponding to a mean decline of 13.90 visits per household per month (SD = 7.086; 95% CI: 12.97–14.87; $p < 0.001$) (Fig. 2). Fuelwood harvest among ICS beneficiaries decreased by about one-third per household from 9.63 kg/day before intervention to 6.76 kg/day after intervention. The mean reduction in fuelwood use was 2.87 kg/day per household (SD = 1.04; 95% CI: 2.72–3.02; $p < 0.001$) (Fig. 3). Across the three villages, average household income increased from ₹3189 (US\$ 35.35) to ₹3977 (US\$ 44.09) per month following the interventions, representing an average increase of approximately 25%. The mean increase in monthly household income was ₹788 (US\$ 8.50; SD = ₹667.2; 95% CI: ₹699–₹876; $p < 0.001$) indicating a statistically significant improvement (Fig. 4). Additionally, secondary benefits were observed among ICS beneficiaries. Spirometry tests among 30% of ICS beneficiaries showed that 61.11% showed marked improvement in respiratory health. A small group of trained beneficiaries became ICS manufacturers and constructed additional units in nearby households for a fee (₹500 per stove on average; US\$ 5.36) as an additional income-generating activity.

The estimated average annual human-tiger negative interactions in the three project villages declined by 46% from 1.86 per year during 2012–2018 (13 incidents) to 1.00 per year during 2019–2025 (7 incidents). A total of four reported instances of public aggression in response to tiger ingressions were documented in project landscape during 2010–2018, whereas, only one such incident was recorded during 2019–2025. Approximately 20% of recorded negative human-tiger interactions involved beneficiaries cooperating to alert response teams and assisting during conflict mitigation operations. The majority of the beneficiaries surveyed (98%; 441 out of 450) reported a positive attitude towards tiger conservation.

These trends are in line with studies that show reduced entry into forests is an important way through which safer livelihood interventions reduce risks of human-tiger negative interactions [6]. Other studies show building economic security may increase tolerance and social capacity towards large carnivores [8,9]. The results illustrate that livelihood diversification and access to energy-efficient cooking solutions can practically contribute towards considerable decrease in forest dependency, increase in household incomes and reduce exposure to high-risk forest-based activities. Overall, the findings demonstrate that when conservation initiatives strengthen socio-economic security at household level, this is likely to improve willingness and social capacity of local people to coexist with wildlife.

Replication and relevance

The study in the Kultali Block of Indian Sundarban demonstrates the following main aspects: (i) livelihoods and conservation outcomes can reinforce one another in the context of a Biosphere Reserve when

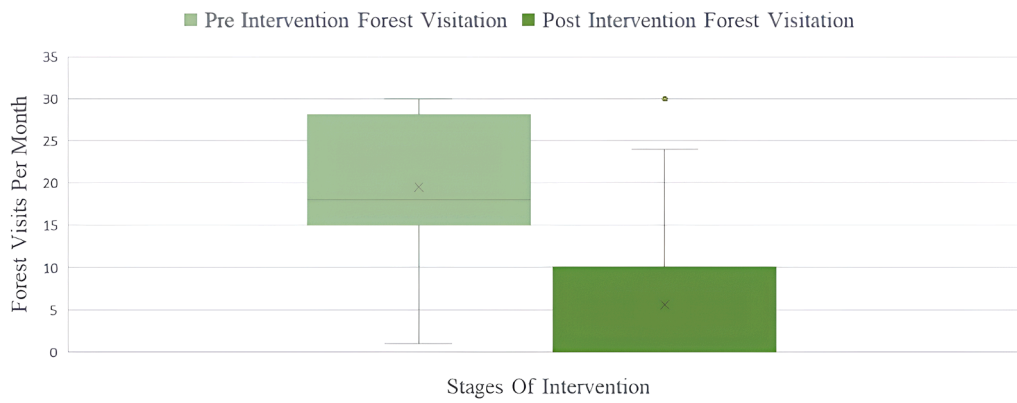


Fig. 2. Box plot showing pre- and post-intervention forest dependency, indicating a decrease in monthly forest visits for fuelwood collection across all villages.



Fig. 3. Box plot showing pre- and post-intervention fuelwood consumption (kg/day), indicating a significant decrease across all villages.

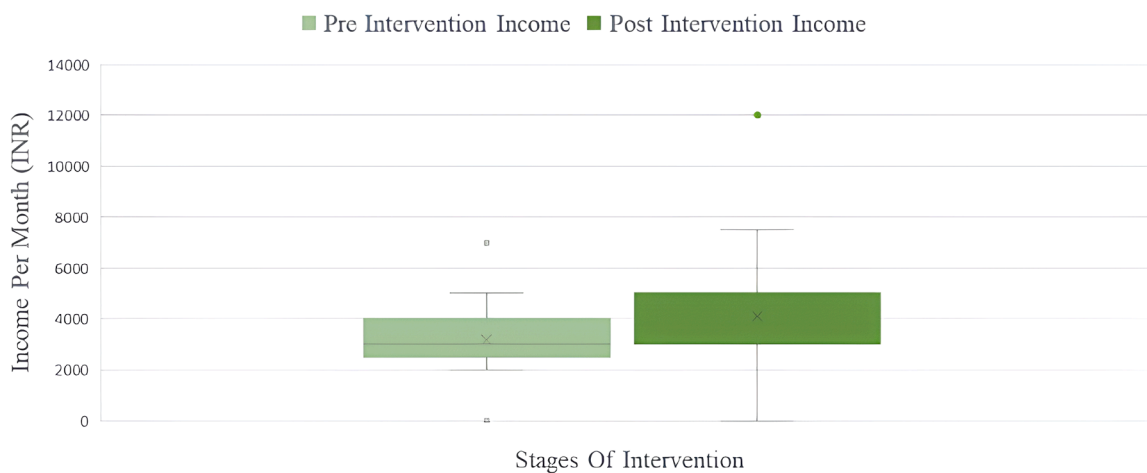


Fig. 4. Box plot showing the increase in monthly household income from goat and poultry rearing before and after the intervention across all villages.

implemented through long-term community-based participatory processes, thereby strengthening human-tiger coexistence; and (ii) social capacity of local communities towards a large carnivore can be improved through context-specific strengthening of safety and efficiency in existing traditional livelihood practices, deeming a complete shift in livelihoods unnecessary. The integrated model combining locally appropriate and safer livelihood options and energy-efficient cooking

system can be adapted to other similar forest-edge landscapes experiencing heavy dependence on forest-based resources by local community and intense human-large carnivore negative interactions.

CRedit authorship contribution statement

Arshia Bajpai: Writing – original draft, Methodology, Formal

analysis, Data curation, Conceptualization. **Santra Karmakar:** Investigation, Data curation. **Prosenjit Sheel:** Project administration, Investigation, Data curation. **Divya Mehra:** Project administration. **Amitava Roy:** Investigation, Data curation. **Abhishek Ghoshal:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Conceptualization. **Samir Kumar Sinha:** Project administration, Investigation.

Ethics statement

This study draws on secondary survey data and monitoring records collected as part of an ongoing conservation and livelihood intervention implemented by the Wildlife Trust of India. All field-level data collection, including respondent engagement and consent procedures, was carried out by the implementing field teams of the Wildlife Trust of India in accordance with their institutional protocols and locally accepted norms.

Participation of community members was voluntary, and Free, Prior and Informed Consent (FPIC) was obtained at the time of data collection by the implementing organization. The lead author did not participate in primary data collection.

Project implementation and survey protocols were conducted in accordance with the ethical guidelines of the International Union for Conservation of Nature (IUCN).

Declaration of Competing Interest

The authors declare no competing interests.

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India, contributed to assess public aggression vis-a-vis human-tiger interaction in the project landscape.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.socimp.2026.100191](https://doi.org/10.1016/j.socimp.2026.100191).

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