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Short Communication

Patterns and determinants of human-elephant conflict in Cauvery North Wildlife Sanctuary, Tamil Nadu, Southern India

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ABSTRACT

The Cauvery North Wildlife Sanctuary in the northern part of Tamil Nadu is part of the Brahmagiri-Nilgiri Eastern Ghat landscape of southern India, a critical habitat for the conservation of the endangered Asian elephant. A foot survey was conducted along the 52 km Protected Area boundary of the Jawalagiri Wildlife Range (Devarabetta and Jawalagiri Section) to assess the status of elephant-proof barriers. Park edge villages within 2.5 km of the eastern margin of the Devarabetta Section were surveyed through convenient sampling to map the distribution of fruit trees that act as elephant attractants. The existing barriers included Elephant Proof Trench (44150 m), Steel Rope Fence (12350 m), Solar Fence (8900 m), and Hanging Solar Fence (4950 m). A total of 138 breakages of varying lengths were recorded across the 4 elephant-proof barriers, totalling 838.88 m. On average, there was one breakage reported across all barriers at every 509.78 m of the study area's overall extent. A total of 297 fruit trees comprising *Artocarpus heterophyllus* and *Tamarindus indica* were recorded in the villages. Of the overall number of *A.heterophyllus* trees, 20.11 % were damaged by elephants, while none of the *T.indica* trees were damaged.

Key words: human-elephantconflict,elephantconflictmitigation, barrier systems, fruiting trees

INTRODUCTION

With 27,312 wild elephants (MoEFCC 2017), India is home to 55% of the total Asian elephant population in the world. Out of this, the highest elephant density, about 6300-6500 elephants, is distributed over 12,000 km2 of the Brahmagiri–Nilgiri–Wayanad–Mysore landscape which extends from the Brahmagiri Hills in the south through the Eastern Ghats in the states of Karnataka, Tamil Nadu, Kerala, and Andhra Pradesh. Hence, this landscape is of immense importance for the conservation of the Asian elephant population (Boominathan et al., 2020).

Elephants have more cerebral cortex accessible for cognitive processing than any other lifeform, which enables this species to acquire a variety of learning and memory-related abilities, including retaining knowledge about conspecifics and its surroundings (EAZA, 2020). Because of this megafauna's size, intellect, and need for a significant amount of space to thrive, efforts to preserve them and their habitats in areas where the human population is growing at an increasingly rapid rate are leading to tensions over habitat and resources, which frequently culminate in Human Elephant Conflict (HEC), the primary reason for the death of Asian elephants in the wild (Hankinson, Nijman & Abdullah, 2020; Williams et al., 2020).

Drivers of Human-Elephant Conflict (HEC)

Elephants are habitat generalists which thrive everywhere, from grasslands to rainforests, because of their resource-use strategies, which are context-dependent (Huang et al., 2019). However, they must move across enormous regions to obtain water, sufficient food and mate at different times of the year. The world's remaining Asian Elephant population currently occupies 5 % of its historical geographical range surviving in highly dispersed groups across 13 nations (Shaffer et al., 2019). Based on a decline in its area of occupancy and the quality of its habitat, the Asian Elephant's population size is assumed to have decreased by at least 50% during the last three generations, and as a result, it is classified as Endangered (EN) by the IUCN (Williams et al., 2019).

Human-elephant conflicts are on the rise as forests are degraded and habitats are dwindling, contributing to the various problems that Asian elephant populations face across the world. Human-Elephant Conflict is a complicated dynamic that reflects the negative influence both people and elephants have on each other (Desai and Riddle, 2015). Elephants penetrate human habitations to graze on agricultural and plantation crops or in quest of water when the carrying capacity of forests declines owing to degradation, causing high levels of conflict and crop destruction.

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In India, every year, there are approximately 400 human deaths and 100 elephant deaths (mostly retaliatory killings) as a result of HEC (MoEFCC 2017). The repercussions of HEC also extend to monetary losses for farmers and officials. For example, a study conducted in Karnataka, during April 2008-March 2011, reported 60,939 incidences of crop loss to elephants, and a total *ex-gratia* of 2.99 million US $ was paid to people affected by HEC (Gubbi et al. 2014).

Preventing and Mitigating HEC

HEC mitigation is mostly viewed as a measure to aid elephant conservation, with some consideration paid to human suffering. Human-elephant conflict prevention techniques try to minimise conflict and mostly deal with wildlife management, stakeholders, and land management, whereas mitigation strategies are generally ascribed to cultural tolerance and a strong prohibition on retaliatory killing of wildlife under the Wildlife Protection Act of 1972. (Reddy et al., 2019). A basic first step in HEC reduction is to address the root sources of conflict. According to Desai and Riddle (2015), the two key components of controlling HEC are guarding, the use of barriers, and other deterrents. Guarding, which can be done from a fixed site or by roving, is an extensively used crop security approach in all Asian elephant range nations. Deterrents attack an elephant's hearing (firecrackers) and olfactory senses (chilli grease on barriers).

A barrier is a physical structure built along a border that may be used for exclusion (preventing elephants from entering an area) or inclusion (containing elephants in a certain region) (Fernando et al., 2008; (Panda, Thomas and Dasgupta, 2020). Elephant Proof Barriers (EPB) are the most common mitigating techniques used to reduce HEC. However, factors such as human or natural sources of damage, lack of maintenance, and faulty design can limit the effectiveness of these barriers. Such systems face significant development and maintenance expenses. Design and park administration are also discovered to influence long-term efficacy(Shaffer et al., 2019).

Elephant conservation in human-dominated areas is mostly dependent on conflict reduction strategies that improve human-elephant cohabitation. As a precautionary measure, the Cauvery North Wildlife Sanctuary (CNWLS) in Tamil Nadu has installed elephant-proof barrier structures around the region. These barriers include elephant proof trenches (EPT), solar fences (SF), hanging solar fences (HSF) and steel rope fences (SRF).

Fruiting Trees as Attractants

Crop damage caused by forest elephants, as well as the consequent human-elephant conflict, are major concerns for both the conservation of the species and the safeguarding of rural livelihoods in the area. According to Ngama et al., (2019), the presence of fruit trees is one of the most important indicators of agricultural loss caused by elephant raids. Even when farmers used deterrence techniques in the study conducted by Ngama et al., the presence of fruiting trees was the most critical factor luring elephants into fields in the research. Both the prevalence of elephant crop damage and the quantity of raiding elephants were highly impacted by the presence of fruiting trees (Ngama et al., 2019). Fruit-bearing trees grow fruit from March through May. During this time, trees like jackfruit (*Artocarpus heterophyllus*), tamarind (*Tamarindus indica*), and mango (*Mangifera indica*), which are often found in rural areas and along public roads, yield fruit, potentially attracting elephants and forcing lone bulls to leave protected areas (Bantalpad, Gayathri and Krishnan, 2017). Elephant migration in human-dominated regions has been discovered to be influenced by fruit trees and their fruits like that seen in wild forest environments (Gayathri & Krishnan, 2017). Elephants are thought to be attracted to tamarind and jackfruit trees in particular.

Objective or purpose of the study:

The purpose of this study was to document the current state of elephant-proof barriers in the Cauvery North Wildlife Sanctuary. In addition, the effects of the presence or absence of *A. heterophyllus* and *T. indica* on the damages caused by elephant proof barrier systems were explored.

MATERIALS AND METHODS

Study Area

The study was carried out in the Cauvery North Wildlife Sanctuary (12.2557 ºN-12.6846 ºN, 77.5812 ºE-77.9739 ºE) which encompasses a total area of 504.334 km^2. The Cauvery North Wildlife Sanctuary is connected to the Bannerghatta National Park on the west via the Thally-Bilikal and Bilikal-Jawalagiri elephant corridors (Menon et al., 2017). The sanctuary predominantly comprises mixed dry deciduous forest and its associated landscape of Hosur and Dharmapuri forest divisions is used by an estimated population of 250 to 499 elephants (CNWLS Wildlife Management Plan 2017, MoEFCC 2017).

The CNWLS has three wildlife ranges, namely Denkanikottai, Jawalagiri, and Anchetty. The Thally – Bilikkal elephant corridor is located in the Jawalagiri Range in The Cauvery North Wildlife Sanctuary (Hosur Forest Division), Tamil Nadu, and Bannerghatta National Park, Karnataka, and has been designated as of high ecological importance. Elephants from Bannerghatta National Park's northern section migrate to the Cauvery Wildlife Sanctuary in Karnataka via the Cauvery North Wildlife Sanctuary in Tamil Nadu and private properties between Dodduru and Belalam villages (Menon et al., 2017). The existence of large-scale farmed crops that are appealing to elephants, as well as rivers, reservoirs, and other water bodies near areas with high elephant populations, creates ideal conditions for human-elephant conflict.

Record and assessment of the status of elephant-proof barriers

An assessment of the elephant-proof barriers was done by following methods used by Gayathri et al (2016). A foot survey was done along the 52 km Protected Area (PA) boundary of the Jawalagiri Wildlife Range (Devarabetta and Jawalagiri Section). To measure the extent of each barrier type, geo-coordinates were noted at every 50 m using a Global Positioning System (GPS). The probable causes for each breakage were recorded based on environmental and manmade factors. The length of breakage was measured using a measuring tape and the damage was photographed at every point of observation.

Status of fruiting trees

Adopted from Medha et al., (2017), park edge villages within 2.5 km of the eastern margin of the Devarabetta Section were selected and surveyed through convenient sampling to map the distribution of fruit trees that act as elephant attractants. A total of 26 villages were surveyed. The fruiting status of the trees and damages by elephants were recorded. The damage to trees was assessed by taking into consideration foraging signs like tusk markings on tree barks and the presence of dung piles in the vicinity. The area of the buffer area in which fruiting trees were sampled was calculated using QGIS and excel. This value was then used to determine the density of fruiting trees in the buffer area.

Data Analysis

Data collected through observation datasheets was digitised using MS Excel.. QGIS was used to conduct a spatial analysis of interactions between variables. The CNWLS boundary shapefile was imported as a base layer into QGIS. The digitised dataset was then imported into QGIS and mapped onto the base layer. The overall extent was categorised into four barrier types and mapped on the shapefile of the CNWLS boundary layer in QGIS.

RESULTS

Current Status of Elephant Proof Barrier Systems

The total extent of the elephant proof barrier systems was 70.35 km, distributed over 33,550 m on the Devarabetta eastern margin and 36,800 m on the Jawalagiri eastern and western margin. It was found that the Jawalagiri Wildlife Range implemented 4 types of elephant-proof barrier systems, namely (EPT), Steel Rope Fence (SRF), Solar Fence (SF), and Hanging Solar Fence (HSF). These were used either as a single barrier or in a combination of multiple barrier systems. The physical extent of these individual barriers has been tabulated below in descending order of length (Table 1).

Status of Elephant Proof Barriers

A total of 138 breakages (Figure 2), amounting to a length of 838.88 m, were encountered, 71 breakages (204.06 m) on the Devarabetta eastern margin and 67 breakages (634.82 m) on the Jawalagiri eastern and western margins (Figure 1). A total of 105 (497.01 m) breakages were encountered in the Elephant proof trench, 155.51 m on the Devarbetta eastern margin and 341.5 m on the Jawalagiri eastern and western margins.

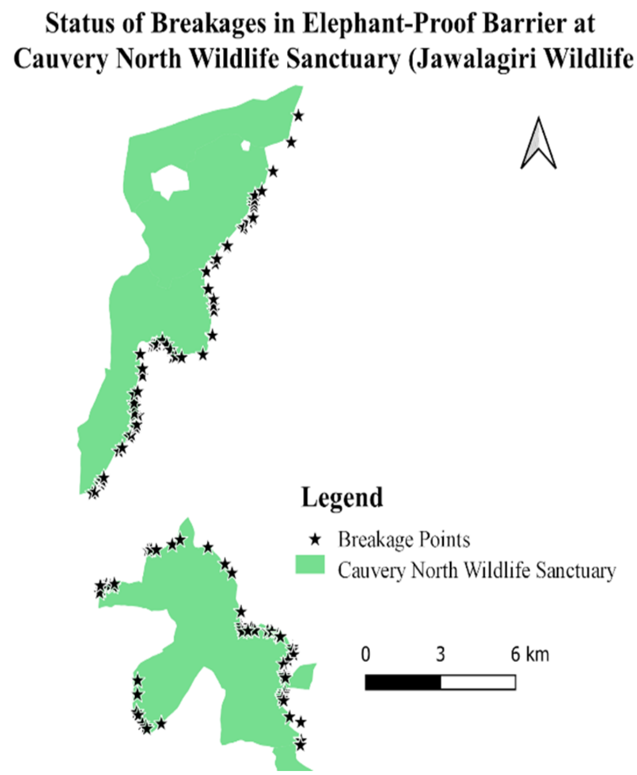

Figure 2. Map of points at which breakages occurred in Elephant Proof Barriers at Cauvery North Wildlife Sanctuary (Jawalagiri Wildlife Range)

Table 1. The total length of the Elephant Proof Barrier Mechanisms installed in Jawalagiri Wildlife Range

S. No.	Barrier Type	Length of the Barrier (m)	Percentage
1	Elephant Proof Trench (EPT)	44150	62.75
2	Steel Rope Fence (SRF)	12350	17.55
3	Solar Fence (SF)	8900	12.65
4	Hanging Solar Fence (HSF)	4950	7

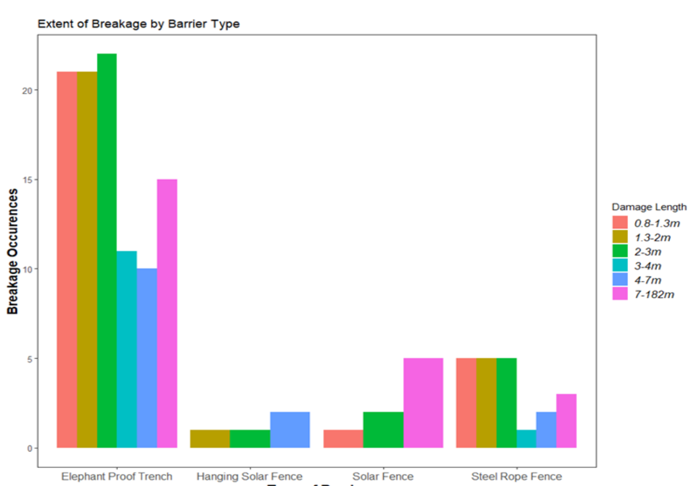

Figure 1. The extent of breakage by barrier type in Cauvery North Wildlife Sanctuary (Jawalagiri Wildlife Range).

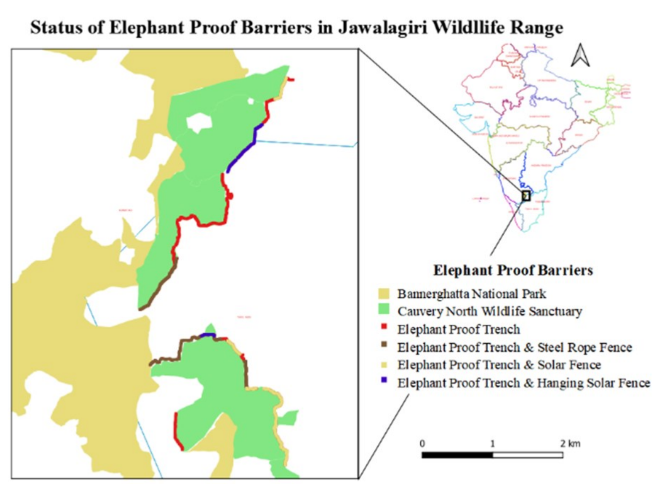

Figure 3. Map of Elephant Proof Barrier Mechanisms in Cauvery North Wildlife Sanctuary (Jawalagiri Wildlife Range)

A total of 20 breakages amounting to a length of 84.3 m were encountered for the steel rope fence, 31.9 m on the Devarbetta eastern margin and 52.4 m on the Jawalagiri eastern and western margins.

A total of 4 breakages amounting to a length of 13.65 m were encountered in the hanging solar fence, 8.65 m on the Devarbetta eastern margin, and 5.0 m on the Jawalagiri eastern margin.

A total of 9 breakages amounting to a length of 243.92 m were encountered in the solar fence; 8.0 m on the Devarbetta eastern margin, and 235.92 m on the Jawalagiri eastern margin.

The average number of breakages across barrier types occurred most where EPTs and SRFs worked as a multiple barrier system (6.70 breakages/km). This was followed by multi-barrier systems which used EPTs and SFs (6.30 breakages/km).

Table 2. The average number of breakagers per kilometer of the different barrier types installed in the Jawalagiri Wildlife Range. (EPT= Elephant Proof Trench, SRF= Steel Rope Fence, SF=Solar Fence and HSF= Hanging Solar Fence)

Barrier Type	Total Length of Barrier (km)	Breakages Occurred	Per kilometre average
EPT	44.15	105	2.38
SRF	12.35	20	1.62
SF	8.9	9	1.01
HSF	4.95	4	0.81
EPT.SRF	10.75	72	6.70
EPT.HSF	3.7	15	4.05
EPT.SF	8.25	52	6.30
EPT.SRF.HSF	1.55	1	0.65

Status of fruiting trees

During the study period, a total of 297 fruit trees comprising *A. heterophyllus* and *T. indica* were mapped within 2.5 km of the eastern border of the Devarabetta section of the Jawalagiri Wildlife Range.

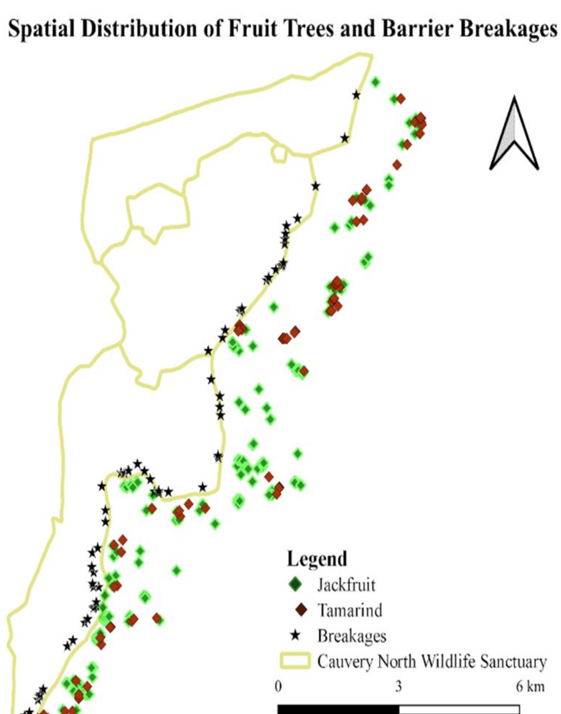

Figure 4. Spatial distribution of the fruit trees mapped within 2.5 km of the eastern border of the Devarabetta section

Out of the 179 *A. heterophyllus* trees, 167 were fruiting, of which 36 were damaged and 12 of the trees were non-fruiting. Out of the 118 *T. indica* trees, 30 were found to be fruiting and 88 non-fruiting. No damage to *T. indica* trees was recorded (Figure 4).

The area of the buffer zone in which fruiting trees were sampled was 26.9 sq kms. The highest tree density was observed in fruiting *A. heterophyllus* trees (6.21 sq. km) and the least in its non-fruiting trees (0.45 sq. km). Non-fruiting *T. indica* trees were the second highest in density (3.27 sq. km) followed by its fruiting variants (1.12 sq. km) (Figure 5).

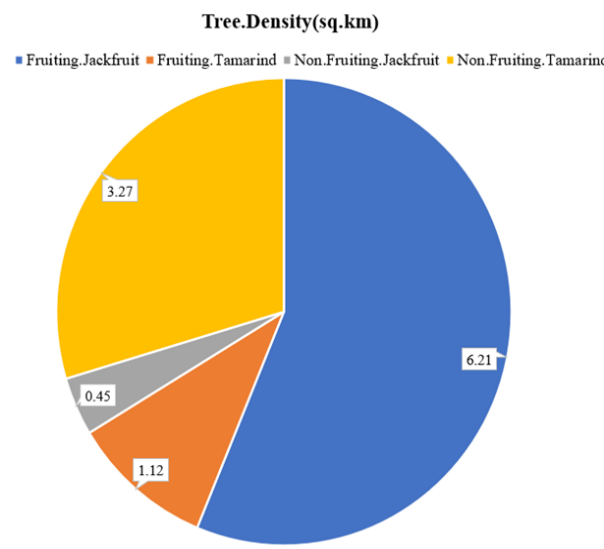

Figure 5. Tree densities of fruiting and non-fruiting *A.heterophyllus* and *T. indica* trees in the buffer area of the Devarabette section.

DISCUSSION

Significance of study area (Jawalagiri Wildlife Range)

All reserve forests inside the Jawalagiri Range are included in the CNWLS Buffer Zone (Bilgi, 2016). The buffer zone's role in forest landscapes is to guarantee habitat integrity, connectivity, and room for species dispersal. The buffer zone would also serve as a sink for elephants migrating from the Karnataka side.

Status of barrier systems

According to the CNWLS management plan (Bilgi, 2016), elephant proof trenches and solar fences have been installed to a total length of 247.45 kilometres, out of a total requirement of 400 kilometres.The results of the foot survey indicated a variety of reasons for individual barriers breaking throughout the research region.

According to an assessment of elephant-proof barriers, elephants are able to recognise weak places on the barriers (Varma et al. 2011). Based on the number of defecations found at breakage points, elephants were suspected to be spending a lot of time at these sites or waiting a long time before using the breakage points to access the town or agriculture grounds.

Man-made breaches, such as on trails established for grazing cattle, natural factors like soil erosion hindering the efficiency of elephant proof trenches, and elephants breaching the barriers have all hampered efforts to reduce HEC using elephant-proof barriers (RE).

Elephant Proof Trenches

The dimensions of the Elephant proof trenches at the time of construction were 3 m (Top width) x 1 m (bottom width) x 2 m (height) (Cauvery North Wildlife Sanctuary Management Plan, 2017).

In Karnataka, Jayant et al. (2007) found that a trench dug alongside an electric fence was particularly successful in reducing human-elephant conflict. Furthermore, farmers have used barrier fencing to fence their property since animals tend to move beyond the perimeters, resulting in a wide area being covered. The findings from this investigation followed a similar pattern, with breakages being much lower where several barriers were implemented, as shown in Figure 4. Both Nath and Sukumar (1998) and Jayant et al. (2007) found private and individually owned fences to be more effective than government-owned fences in reducing crop-raiding by elephants in Karnataka.

Figure 6. Breakage on EPT

Villagers who dig mud paths into the forest for cattle grazing and collecting forest by-products may reduce the barrier's effectiveness. Other factors include the construction of poorly planned trenches, the dumping of mine waste and garbage into them, and the joining of two or more trenches, all of which reduce the viability of the trenches (Varma, Avinash and Vinay, 2011). While mudslides and landslides cause significant damage, water and rainwater action on elephant proof barriers, particularly elephant proof trenches (EPT), reduces their effectiveness (Singh, 2021). Rainwater flowing from farmland or forest breaks into the trenches, creating a channel and flooding, as well as mud.

Villagers are said to have used the reduced depth to create a vehicle and mud path into the forest for cattle grazing. It should be noted that the cause of trench and fence damage in some cases is unknown and can only be speculated upon.

Trenches have a key disadvantage in that they facilitate soil erosion when excavated on a slope (Figure 5). Elephants have also been observed to fill holes by kicking earth from the trench's borders into it, allowing them to pass through. Trenches need a significant initial labour commitment as well as ongoing upkeep. As shown in Figure 5, soil erosion was thought to be the source of the majority of the damage in EPTs throughout this investigation.

Solar Fences

According to a study conducted by Vibha, Lingaraju, and Venkataramna in 2021, solar fencing is considered to be the most effective way to mitigate conflict between humans and elephants. Considering the solar fence observed in CNWLS was only 12% of the barriers, with 9 breakages, it is difficult to deduce if the results are in line with the above paper. Solar panels are frequently connected with maintenance issues and vegetation growth, which leads to power leaks and obscures the fence, making it less effective (Shaffer et al., 2019).

Even though locals view electric fences as a permanent solution and there is a tendency to put fences wherever there is conflict, there is a significant likelihood of electric fence failure (Lenin and Sukumar 2011). These fences are costly to erect, demand frequent and high maintenance, and the community must be educated on technical knowledge (Palminteri, 2017). Given that the individuals that are subjected to HEC are generally from low-income households, their inability to maintain the fences might be ascribed to solar fence failure. To address this issue, the government should consider promoting a subsidy scheme for solar fence installation, as well as providing monetary assistance to farmers for solar fence maintenance.

Figure 7. Breakage on Solar Fence

In Marakaradoddi, Gurnapalli, Kombarakottai, and Kallubalam villages in the Jawalagiri section, the solar fence was found to be completely dysfunctional, suspected to be caused by elephant damage (Figure 6). In places, the continuity of the solar fence was also disrupted by cattle gates. The efficiency of this barrier was also reduced due to the increase in distance between the bottom wire and the ground.

Furthermore, some elephants adapt to continuous exposure, rendering the electric fence useless once the elephant learns to breach it. They do it by walking over the fence with the thick soles of their feet to compress the wires, utilising tusks (male) that do not carry electricity, pushing or kicking down fence posts, and pushing or kicking down fence posts with their tusks (male) (Chakraborty & Paul, 2021).

In one investigation, roughly 5 EPT and electric fence breakages were documented every kilometer (Varma et al. 2011). According to the same research, farmers anticipated government agencies to provide frequent meetings, compensation for crop loss, permanent physical barriers, elephant relocation, support in chasing elephants, and a solar fence surrounding their fields as some of the mitigating measures. Regular meetings and permanent barriers were the most preferred measures among these recommendations.

In our study, it was unclear if breakages are created by elephants and then exploited by humans, vice versa to enable elephant ingress into agriculture. However, if man-made and elephant-made reasons are addressed, natural phenomena-induced causes are another crucial task to overcome (Varma, Avinash and Vinay, 2011).

Hanging Solar Fences

In Sri Lanka, hanging solar fences have become popular for minimizing human conflict however, their effectiveness is still restricted. The solar-powered wires are suspended from a pole and shock the elephants when they come into contact with them. In November 2019, the Karnataka Forest Department constructed a solar-powered hanging fence in Kodagu district on an experimental basis to reduce the threat of elephants in human habitations, particularly on the outskirts of the forest (DHNS, 2019).

A 5 km hanging fence along the Manas National Park perimeter was successfully tested and showed promise in Assam as an effective way to prevent human-elephant conflict. However, because these fences are constantly toppled by elephants who collapse traditional fence posts, the expense of upkeep is greater. The local community and the Assam Forest Department have reported that there have been fewer human-elephant interactions in this area, which is positive. The main benefit of these fences is that they are considerably taller (14 ft) than traditional fences and are also electrically charged (solar) to give pachyderms a little shock when they come into contact with them.(Wildlife Trust of India, 2020).

The Kerala state government also plans to erect hanging solar power fences along a 685-kilometre length to drive wild animals away from human settlements, according to a news release dated February 2022. The state planning board is now considering the INR 1,150 crore project (Thiruvananthapuram News, 2022). At times, there was a discontinuity in the hanging solar fence due to wind and clearance by humans for cattle movement.

Low-hanging electric cables are an issue for forests in two ways. Elephants are at risk of electrocution if they come into contact with these lines. In 2013, two elephants perished as a result of electrocution in the Sami Eri reserve forest. Climbing vines can also come into contact with live wires, causing fires as a result of the spark. Climbers surrounding poles and vegetation around power wires should be kept in check.

Steel Rope Fences

The Hosur Forest Division and Kenneth Anderson Nature Society have developed a wire rope fence based on the Addo National Park's Armstrong fence that has significantly reduced human-elephant conflict in the Cauvery North Wildlife Sanctuary (Bilgi and Kumar, 2021). Where other precautions, such as solar fences and elephant proof tunnels, failed, this wire rope barrier proved successful. Human-elephant conflict decreased from hundreds to a handful of incidents each year along the 20-kilometre forest boundary where the fence had been built (Kenneth Anderson Nature Society, 2020). This barrier was built from the ground up and thoroughly tested to guarantee that it is safe, effective, and long-lasting.The barrier was then built along a 13-kilometre stretch of forest boundaries, with funding provided by the Tamil Nadu Innovations Initiatives. Poor farmers were able to harvest a complete crop for the first time in years. The number of elephants attacking crops has decreased dramatically (Anon, KANS conservation).

The success of steel wire rope fencing installed by Tamil Nadu foresters in the Cauvery Wildlife Sanctuary near Hosur will be emulated in Karnataka's Nagarahole Tiger Reserve. In NTR, the Karnataka Forest Department will employ steel wire fencing instead of solar or rail barriers for the first time to keep elephants from leaving the forest. According to the director of the NTR, "Elephants do not have a stable basis to stand or rest on in this approach. The steel ropes will bounce back, causing the animal to get confused. The elephant will be unable to climb over the ropes due to a lack of grip. Our higher authorities have permitted us to execute it in Nagarahole. We must now locate makers of such rope." The steel ropes will be identical to those used to build bridges and will be tested on a 5-kilometre length in the NTR's Veeranahosahalli range, where human-elephant conflict is an issue. Steel ropes are also less expensive than rail barriers. According to department officials, a kilometre of rail barrier costs Rs 1.2-1.3 crore, but steel ropes placed in Tamil Nadu cost only Rs 50-55 lakh per kilometre (Khanna, 2022).

The Tamil Nadu forest department constructed a 2 km long steel wire fence to keep wild elephants from entering residential areas after receiving repeated complaints from locals in the Thally and Jawalagiri forests about crop-raiding by elephants. For at least six months each year, farmers in this region have complained of wild elephants raiding their crops. Elephant herds from Karnataka's Bannerghatta National Park and Cauvery Wildlife Sanctuary used to migrate to Tamil Nadu around October. Villagers plant finger-millet and a variety of vegetables, which are quickly destroyed when elephants assault their farms. Farmers lost a significant amount of money as a result of this. As a result, it was decided to put a barrier around one particular section through which elephants reach the communities on a trial basis. The barrier has now been built over a distance of 2 kilometres, with a 10-kilometre section to be covered with a similar fence in the future (Oppili, 2019).

In the case of a steel rope fence, the efficiency was reduced due to the increase in distance between the bottom rope and the ground due to streams that cut through, cattle trail, and lack of proper planning while construction (Figure 8). In the case of multiple barrier systems (EPT implemented alongside Solar fence and Hanging Solar fence), the efficiency of the system was found to be compromised with a large inter distance between the individual barriers.

In terms of effectiveness of barrier systems, only 1 point of breakage measuring 5 meters was observed where three barrier systems were used in

Figure 8. Water body obstructing Steel Rope Fence

in combination. These were the EPT, SRF and HSF which as standalone barriers were damaged approximately once every kilometer of the barrier (Table 2).

Attractant trees

Reducing the reasons why elephants leave protected areas is another method for lowering human-elephant interactions and thereby preventing conflicts. The presence of water and salt blocks, as well as the planting of palpatable fruit trees inside parks and reserves, may deter elephants from leaving because their spatial movement and use are influenced by their search for food and water.''

Elephants are enticed to crop raids by the cultivation of appealing crops in corridor peripheral regions. Elephants invade agricultural regions on purpose, preferring the flavour and nutritional content of the crops to that of wild vegetation (Naha et al., 2020). Plants from the Moraceae (which includes jackfruit) and Fabaceae (which includes tamarind) families, for example, were widely planted in north-east India, where trespassing elephants traversed 40 active pathways with varying regularity. Elephants consumed Moraceae members more than those of Fabaceae, which was also observed in a foraging ecology study conducted in Northern Thailand (Schwarz, Johncola and Hammer, 2020). Growing particular crops in the past, such as mango and sugarcane, provided ideal habitat for animals and altered wildlife distribution in India (Shamsuddoha & Aziz, 2021). Residents said elephants favoured conventional crops (rice, maize, wheat), garden fruit trees (banana, mango, jackfruit), and home garden plants in a poll of 1182 homes (bamboo, broom grass).

Non-fruiting trees were consumed mostly in regions near damaged fruit trees or areas closer to the Park Boundary, according to research that looked at how tree fruiting affects elephant foraging habits (Medha et al., 2017). This pattern, according to the authors, shows that fruit trees and their fruits impact elephant migration in human-dominated areas in a similar way to the pattern found in natural forest areas. Elephant foraging preferences were evaluated using preference ratios for the three species in the same research, and *A. heterophyllus* trees were shown to have a higher foraging susceptibility than *T. indica* and *M. indica* trees. Wild elephants were thought to be attracted to the fruits of *A. heterophyllus* and *T. indica*.

In this study, 36 of the 179 total jackfruit trees were found to be damaged while no damage was recorded in the tamarind trees. This could be accounted for by the period of the study which was between March-April, post-harvest of the tamarind fruits which act as elephant attractants. The presence of elephant attractant trees like *A.heterophyllus* and *T.indica* in the surrounding park edge villages could have contributed to the Human-Elephant Conflict in this region. Dodduru, Iyyanaradoddi, Malgamdoddi, Bettahalli, Terubethi, Kumbaradoddi, Karadidooi, Yaluvanatha, and Kadushivanahalli are human settlements that lie between the Thally State forest of CNWLS and Bilikkal State forest of the adjoining Bannerghatta National Park. These settlements are considered to be hotspots for HEC owing to their proximity to forest areas. If properly functioning and regularly maintained barriers are implemented in the Nelmaru forest adjacent to the Jawalagiri state forest, HEC can be minimised. This would be because this area is already one of the existing elephant routes established as Jawalagiri-Nelmaru-Thally.

One of the findings from this study indicated that the presence of fruiting trees and/or available crops did not limit elephants from moving into human settlements. The fenceswhich have recently been put up in the Thally-Bilikal corridor, along the Jawalagiri Range's forest boundary could potentially contribute to such non -seasonal HEC patterns (Menonet al., 2017).

CONCLUSION

To the best of our knowledge, this is the first study to look into the status of barriers in the Jawalagiri wildlife range of the Cauvery North Wildlife Sanctuary. The Thally and Jawalagiri Reserve Forests must be rigorously maintained to allow elephants to migrate between the Bannerghatta National Park in Karnataka and the Cauvery North Wildlife Sanctuary in Tamil Nadu. The findings of this study will serve as a first step in determining the efficacy of barrier systems in reducing human-elephant conflict. When assessing barrier systems, it will be necessary to take factors which cause damage to barriers in order to avoid future concern. A few examples of such factors which were encountered in this study includeinvasive species, encroached lands and roadways being constructed through park-edge settlements. Furthermore, a study on the efficiency of HEC mitigation will help in the creation of a safe path for elephant herds migrating from the neighbouring Karnataka forest through the woods of Krishnagiri District's Jawalagiri and Denkanikottai. These elephants will continue their eastward movement to the Venkateshwara and Kaudinya wildlife sanctuary in Andhra Pradesh's Chittoor district.

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REFERENCES

Bantalpad, M., Gayathri, A. and Krishnan, A. (2017). Seasonal Crop Raiding of Fruit Trees by Asian Elephants: An Insight into Foraging Preferences from Croplands Abutting Bannerghatta National Park, Bengaluru, Karnataka, India. *Asian Journal of Environment & Ecology*, [online] 2(2), pp.1–12. doi:10.9734/ajee/2017/31851.

Bilgi, D.S. (2016). *WIldlife Management Plan, 2017-2022, Cauvery North Wildlife Sanctuary*. Tamil Nadu Forest Department.

Bilgi, D.S. and Kumar, S.R.S. (2021). The Melagiri Elephant Fence - A Crucial tool for Human-Elephant Control. *The Indian Forester*, [online] 147(10), p.921. doi:10.36808/if/2021/v147i10/154316.

Boominathan, D., Mohanraj, N., Bhale, S., Santhanaraman, M. and Desai, A.A. (2020). Securing the Segur plateau, a Crucial Elephant Corridor. In: *Trumpet: A quarterly newsletter*. [online] Project Elephant Division and Elephant Cell, Wildlife Institute of India, pp.11–16. Available at: https://moef.gov.in/wp-content/uploads/2021/03/Newsletter_Final_TRUMPET_March-9_2021__compressed.pdf.

Booth, S. (2021). *Health Benefits of Jackfruit*. *WebMD*. Available at: https://www.webmd.com/food-recipes/health-benefits-jackfruit.

Chakraboty, S. and Paul, N. (2021). Efficacy of different human-elephant conflict prevention and mitigation techniques practiced in West Bengal, India. *Notulae Scientia Biologicae*, 13(3), p.11017. doi:10.15835/nsb13311017.

DHNS, S. (2019). Hanging solar fence to check jumbo menace. *Deccan Herald*. [online] 17 Apr. Available at: https://www.deccanherald.com/state/mangaluru/hanging-solar-fence-to-check-jumbo-menace-729213.html [Accessed 3 Apr. 2022].

DHNS, S. (2019). Hanging solar fence to check jumbo menace. *Deccan Herald*. [online] 17 Apr. Available at: https://www.deccanherald.com/state/mangaluru/hanging-solar-fence-to-check-jumbo-menace-729213.html [Accessed 3 Apr. 2022].

EAZA (2020). *Best Practice Guidelines for Elephants (2nd ed.)*. [online] Amsterdam: European Association of Zoos and Aquaria (EAZA), pp.5–28. Available at: https://www.eaza.net/assets/Uploads/CCC/BPG-2020/Elephant-TAG-BPG-2020.pdf.

Fernando, P. (2020). *Guide for Implementing Community-Based Electric Fences: For the effective mitigation of human-elephant conflict*. [online] Washington DC: The World Bank. Available at: http://pubdocs.worldbank.org/en/640461601077146570/ELECTRIC-GUIDE-For-fence25-Sept2020.pdf.

Gayathri, A., Sulaiman, A., Kumar A. V., D., Phalke, S. and Krishnan, A. (2016). *Status of Elephant Proof Barrier Mechanisms in Bannerghatta National Park*. A Rocha India.

Gubbi et.al., (2014) 'An elephantine challenge: Human-elephant conflict distribution in the largest Asian elephant population, southern India', Biodiversity and Conservation, 23, pp. 633-647. DOI: https://doi.org/10.1007/s10531-014-0621-x.

Hankinson, E., Nijman, V. and Abdullah (2020). Asian Elephants: 15 years of research and conservation. *Journal of Physics: Conference Series*, [online] 1460, p.012055. doi:10.1088/1742-6596/1460/1/012055.

Huang, C., Li, X., Khanal, L. and Jiang, X. (2019). Habitat suitability and connectivity inform a co-management policy of protected area network for Asian elephants in China. *PeerJ*, [online] 7. doi:10.7717/peerj.6791.

Jayasuriya, N., Sayakkara, A., Suduwella, C., Keppitiyagama, C., De Zoysa, K., Hewage, K. and Voigt, T. (2017). 'Wire is not dead': Wired-backscatter Communication for Breakage Detection in Electric Fences. In: *International Conference on Embedded Wireless Systems and Networks (EWSN)*. [online] Workshop on Next Generation Platforms for the Cyber-Physical Internet. pp.300–304. Available at: https://www.researchgate.net/publication/315656965_Wire_is_not_dead_Wired-backscatter_Communication_for_Breakage_Detection_in_Electric_Fences.

Kenneth Anderson Nature Society (2020). *Wire rope fence to prevent human elephant conflict*. *www.youtube.com*. Available at: https://www.youtube.com/watch?v=vbk9GJ8ROUI [Accessed 3 Apr. 2022].

Khanna, B. (2022). Karnataka to use steel wires to stop jumbos from straying out of forests. *The New Indian Express*. [online] 14 Feb. Available at: https://www.newindianexpress.com/states/karnataka/2022/feb/14/karnataka-to-use-steel-wires-to-stop-jumbos-from-straying-out-of-forests-2419073.html [Accessed 3 Apr. 2022].

Manral, U., Sengupta, S., Ainul Hussain, S., Rana, S. and Badola, R. (2016). Human wildlife conflict in india: a review of economic implication of loss and preventive measures. *The Indian Forester*, [online] 142(10), pp.928–940. Available at: index.php/indianforester/article/view/93647.

Menon, V., Tiwari, S., Ramkumar, K., Kyarong, S., Ganguly, U. and Sukumar, R. (2017). *Right of Passage: Elephant Corridors of India*. 2nd ed. [online] New Delhi: Wildlife Trust of India. Available at: https://www.wti.org.in/wp-content/uploads/2017/08/pub_right_of_passage-1.pdf.

Naha, D., Dash, S.K., Chettri, A., Roy, A. and Sathyakumar, S. (2020). Elephants in the neighborhood: patterns of crop-raiding by Asian elephants within a fragmented landscape of Eastern India. *PeerJ*, 8, p.e9399. doi:10.7717/peerj.9399.

Ngama, S., Bindelle, J., Poulsen, J.R., Hornick, J.-L., Linden, A., Korte, L., Doucet, J.-L. and Vermeulen, C. (2019). Do topography and fruit presence influence occurrence and intensity of crop-raiding by forest elephants (Loxodonta africana cyclotis)? *PLOS ONE*, [online] 14(3), p.e0213971. doi:10.1371/journal.pone.0213971.

Oppili, P. (2019). Steel wire fence to stop jumbos from straying into farm lands | Chennai News - Times of India. *The Times of India*. [online] 14 Jan. Available at: https://timesofindia.indiatimes.com/city/chennai/che-steel-wire-rope-fence-to-stop-elephants-straying-into-farm-lands/articleshow/67517753.cms [Accessed 3 Apr. 2022].

Palminteri, S. (2017). Breaking a fence-breaking habit: maintaining the fences that reduce human-elephant conflict. *Mongabay Environmental News*. [online] 2 Jun. Available at: https://news.mongabay.com/2017/06/breaking-a-fence-breaking-habit-maintaining-the-fences-that-reduce-human-elephant-conflict/ [Accessed 6 Aug. 2022].

Panda, P.P., Thomas, N. and Dasgupta, S. (2020). *Best Practices Management in India Best Practices of Human Elephant Conflict Management in India Human Elephant Conflict Ministry of Environment, Forest & Climate Change*. [online] Dehradun, Uttarakhand: Elephant Cell, Wildlife Institute of India. Available at: https://static.pib.gov.in/WriteReadData/userfiles/HEC-Brochure-%20Version%208-min.pdf [Accessed 3 Apr. 2022].

Perera, B.M.A.O. (2009). The Human-Elephant Conflict: A Review of Current Status and Mitigation Methods. *Gajaha*, [online] 30, pp.41–52. Available at: https://maraelephantproject.org/wp-content/uploads/2016/04/The-Human-Elephant-Conflict-A-Review-of-Current-Status-and-Mitigation-Methods.pdf [Accessed 25 Jul. 2021].

Raja, J.A. and Vani, R. (2020). A Study On The Issues Of Human Elephant Conflict With Reference To Dharmapuri And Krishnagiri Districts. *Karpagam Journal Of Commerce And Management*, [online] 1(1). Available at: https://karpagampublications.com/wp-content/uploads/2020/09/Human-Elephant-Conflict.pdf.

Reddy, A., Vanamamalai, A., Gupta, S. and Karanth, D.K. (2019). *Human-Wildlife Conflict in Karnataka: The Need for a Human-Wildlife Conflict Compensation LAw*. [online] Vidhi Centre for Legal Policy, Centre for Wildlife Studies. Available at: https://vidhilegalpolicy.in/wp-content/uploads/2020/06/Human-wildlife-conflict-Karnataka.pdf.

Saaban, S., Yasak, M.N., Gumal, M., Oziar, A., Cheong, F., Shaari, Z., Tyson, M. and Hedges, S. (2020). Viability and management of the Asian elephant (*Elephas maximus*) population in the Endau Rompin landscape, Peninsular Malaysia. *PeerJ*, [online] 8. doi:10.7717/peerj.8209.

Schwarz, C., Johncola, A. and Hammer, M. (2020). Foraging Ecology of Semi-Free-Roaming Asian Elephants in Northern Thailand. *Gajah*, [online] 52, pp.4–14. doi:10.5281/zenodo.4070865.

Shaffer, L.J., Khadka, K.K., Van Den Hoek, J. and Naithani, K.J. (2019). Human-Elephant Conflict: a Review of Current Management Strategies and Future Directions. *Frontiers in Ecology and Evolution*, [online] 6. Available at: https://www.frontiersin.org/articles/10.3389/fevo.2018.00235/full#h5.

Shamsuddoha, M. and Aziz, M.A. (2021). Human-Elephant interactions and associated damage in the northern transboundary areas of Bangladesh. *Our Nature*, [online] 19(1), pp.10–17. doi:10.3126/on.v19i1.41213.

Singh, B.K. (2021). Restore elephant habitats and corridors. *The Hans News Service India*. [online] 11 Aug. Available at: https://www.thehansindia.com/hans/opinion/news-analysis/restore-elephant-habitats-and-corridors-701112?infinitescroll=1 [Accessed 7 Aug. 2022].

Thiruvananthapuram News (2022). Govt Plans To Install Hanging Solar Fence. *The Times of India*. [online] 25 Feb. Available at: https://timesofindia.indiatimes.com/city/thiruvananthapuram/govt-plans-to-install-hanging-solar-fence/articleshow/89812524.cms [Accessed 3 Apr. 2022].

Varma S. et.al. (2009) Ecology, Conservation and Management of the Asian Elephant in Bannerghatta National Park, Southern India. 2nd edn. Bangalore: A Rocha India and Asian Nature Conservation Foundation.

Varma, S., Avinash, K.G. and Vinay, L. (2011). *Human-Elephant Conflict in Mysore Forest Division*. [online] Bangalore: Asian Nature Conservation Foundation (ANCF). Available at: http://www.asiannature.org/sites/default/files/2011%20HEC-Mysore-FD.pdf [Accessed 2011].

Wildlife Trust of India (2020). Hanging Fences Protect People and Elephants in Manas. *WTI*. [online] 7 May. Available at: https://www.wti.org.in/news/hanging-fences-protect-people-and-elephants-in-manas/ [Accessed 3 Apr. 2022].

Williams, C., Tiwari, S.K., Goswami, V.R., de Silva, S., Kumar, A., Baskaran, N., Yoganand, K. and Menon, V. (2019). *Elephas maximus*: Williams, C., Tiwari, S.K., Goswami, V.R., de Silva, S., Kumar, A., Baskaran, N., Yoganand, K. & Menon, V. *IUCN Red List of Threatened Species*. [online] doi:10.2305/iucn.uk.2020-3.rlts.t7140a45818198.en.