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CONFLICTS BETWEEN LINEAR DEVELOPMENTS AND ASIAN ELEPHANTS IN SUB - HIMALAYAN ZONE OF UTTRANCHAL (INDIA)

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Abstract: As a consequence of recent habitat fragmentation, the free movement of Asian elephants all over India has been disrupted to a great extent. The very existence of this largest terrestrial mammal is now under threat for various reasons, such as persecution for its ivory and blockage of migratory routes due to construction of many developmental projects. Shrinkage of elephants' habitats due to linear developments (rail lines, roads, canals, and human habitation) in and around the protected areas give rise to foraging and migratory problems, resulting ultimately in man-elephant conflicts, confrontation among herds, and accidental deaths. The present paper discusses in detail threats faced by wild Asian elephants in the sub-Himalayan region in Rajaji National Park, Uttranchal, India. Various case studies of difficulties faced by elephants because of rail lines, roads, and irrigation and hydroelectric canals in the region have also been discussed. River Ganges flows through the habitat for about 24.0 km and divides it in two parts. The man-made barriers have shrunk the width of habitat along the river Ganges from 24.0 km to roughly 4.0 km. The rail line and road on the right and the irrigation and hydroelectric canal on the left of the Ganges have restricted the access of the elephants to the legendary river Ganges, the irresistible attraction for the wild Asian elephants, which they have to visit daily for drinking, bathing, and beating the heat in summer months. Therefore, the elephants look for alternate sources of water and food, and as a result, they enter human habitation and croplands, leading to the man-elephant conflicts. Moreover, with rail tracks in the vicinity, there have been numerous elephant deaths due to speeding trains. The frequent confrontations of elephants with moving traffic on rail lines and roads have made them irritable, restless, and prone to accidents. This paper examines the disastrous effects of incompatible design and construction of crossings on the age-old migration tracks and the existing linear developments and how they could be rectified in an animal-friendly way. The paper also suggests practical solutions to reduce the threats to elephants and to their habitats, ensuring sustainability of viable elephant populations in a habitat shrunk by human activity.

Introduction

Economic development was the priority in India after independence. Therefore, a chain of development activities was initiated throughout the country. The entire upland area of north India including the present Uttranchal has been facing the problem of poverty, malnutrition, energy, food, and inaccessibility. For solving the problem of inaccessibility, energy, and food in the different terrain at the foothills, a comprehensive plan of linear development (rail lines, roads, and canals, etc) has been launched. The study area (Uttranchal) is very rich in the diversity of wildlife. The area is known as the abode for the giant mammal - elephant. As a consequence of expansion of linear developments (hydroelectric and irrigation canals, power lines, rail lines, and roads, etc.), the natural habitat of this very important and vulnerable animal has been fragmented and damaged to a great extent.

The paper highlights the various impediments and obstructions due to linear developments in the natural habitat and the remedial measures and solutions of various specific problems arising, particularly in the study area and specific to this biggest mammal of the land. These impediments have forced this biggest mammal of the land to live in isolated patches of forests, which is a very dangerous trend for the long-term survival of this majestic creature of the wild.

The main focus of this paper is to generate practical and innovative ideas pertaining to the various engineering structures on the movement tracks of the elephants and their modalities, vis-a-vis maintaining a balance by creating eco-friendly mitigating structures between isolated forest patches, which are acceptable to their basic instinct and liking. Until today, the mitigation structure across the linear developments for big mammals like elephants have not been constructed in any elephant-populated countries in Asia and Africa. So, an in-depth study and expertise will be required in handling this problem. Mitigation structures (underpasses and overpasses) across the linear developments for small mammals have been successfully constructed in the

developed countries, like USA, Canada, New Zealand, Netherlands, and Norway. Small mammals are using these structures with ease. Due to all these problems and the danger of extermination of the Asiatic elephants, urgent measures are required for maintaining the survival of their population in this area.

The African elephants population is between 4,00,000 to 6,00,000, which are living in 5.9 million km² areas where the Asian elephants are between 35,000 to 50,000, and they are living in an area of 0.44 million km². The Asian elephant population in India is between 19,000 and 29,000 (Kemf and Santipillai 2000).

A substantial amount of work has already been done on the wildlife biology of elephants (Khan 1995; Singh 1987; Johnsingh et al. 1990, 1992, 1999; William et al. 1998). However, no in-depth study of man-elephant conflicts with reference to linear developments has been made; therefore, it was felt desirable to undertake work on this present aspect.

Materials and Methods

For studying the conflicts between linear developments and Asian elephants, the entire area of the sub-Himalayan zone (newly created state of Uttranchal state) in India was surveyed thoroughly for about three to four years. The specific feeding and mating grounds of elephants were visited frequently. For studying the various type of ecological responses, including the mating behavior of Asian elephants, a close watch during day time and even during night were made with all precautionary safety measures. The causes of conflicts and the spots of the accidental deaths in train accidents of elephants were thoroughly investigated from both angles, i.e., civil engineering and ecological points of view. The behaviour of elephants while using the existing civil engineering structures constructed on linear developments was observed in depth. The train driving staff, staff of forest department, peoples of the adjoining areas of the park, and the scientists/engineers working in the area, particularly from the Gurukul Kangri University, Haridwar, H.N.B. University, Srinagar Garhwal, Wildlife Institute of India, Dehradun, U.P. State Irrigation Department, Uttar Pradesh, and other individuals working on this problem, were interviewed. The traffic survey was done in August 2001 for a continuous 24 hours for both sides of traffic.

Physiography of the Study Area

The study area consists of a major part of Rajaji National Park and adjoining areas lying in the foothills of Sivalik ranges and Gharwal Himalayas, which are a major part of elephant habitat, and also the terminal point of the northwestern elephant population range. The population of Northwestern elephants from river Yamuna to river Sharda, approximately 1,500 individuals, are divided into four zones due to the presence of linear developments and other developmental activities in and around their habitat. As per the latest census (2001), approximately 453 elephants are in the Rajaji National Park, of which 111 are males, 238 females, 49 calves (>10 years), and 55 calves (<10 years).

The Rajaji National Park lies between 29° 52' to 30° 16' N and 77° 52' to 78° 22' E of Dehradun, Haridwar, and Pauri districts of the State of Uttranchal, India.

The total area of the Park is 820 km². The Holy Ganges, the only perennial source of water in the Park, flows through the Park for a distance of 24 km. and divides the Park into two unequal halves, (western portion -right bank: 571 km², eastern portion -left bank: 249 km²). The area comprises the fragile Sivalik ecosystem. The flora and fauna of this region have close affinity with those of the Himalayas and Gangetic biogeographic zones (2 and 7 categories of classification of Rodgers and Pawar 1988).

The area under study is largely covered with 'moist deciduous forest' (Champion and Seth 1968) with the subtypes of moist Sivalik Sal (*Shorea robusta*), moist Bhabhar Dun Sal, and dry Sivalik Sal, covering 75 percent of the Park area, and the remaining area is mostly under mixed forest. The region consists of the most important species of elephant (*Elephas maximus*), and there are other carnivorous, herbivorous, and omnivorous species of wild animals, like sambhar (*Cervus unicolor*), barking deer, (*Muntiacus muntjak*), gharial (*Nemorhaedus goral*), nilgai (*Boselaphus tragocamelus*), common langur (*Presbytis entellus*), wild boar (*Sus scrofa*), tiger (*Panthera tigris*), leopard (*Panthera pardus*), jackal (*Canis aureus*), and reptiles like the python (*Python molorus*), king cobra (*Ophiophagus hannah*), and common krait (*Bungarus careruleus*). Besides these animals there are 315 bird species in the Park, including resident and migratory, land and water birds.

There are three major linear developments [rail lines and roads on the right bank (West bank) and the power canal of Chilla hydroelectric project and irrigation canal of the eastern Ganges irrigation project on the right bank (East bank) of river Ganges], which are basically responsible for the blockage of migration of the elephants across the river Ganges from either side.

Developmental Projects and Habitat Fragmentation

Developmental projects, mainly rail lines, roads, canals, industrial establishments, and the encroachment by human habitation, are basically responsible for the fragmentation of habitat and blockade of migratory routes. The movement of herds in the Chilla-Motichur and Rajaji-Corbett corridor in the Rajaji-Corbett elephant range has been almost stopped due to these activities.

Rail Line

The Haridwar-Dehradun/Rishikesh rail line situated on the West bank (right bank), of the river Ganges passes through a 23.0 km stretch of Park, out of which a 18.0 km stretch of the rail line is the accident prone zone between Motichur and Kansaro. This 100-year-old rail line has now become very busy due to the introduction of fast moving trains. Approximately 29 passenger trains and one to two goods trains pass daily on this track. The rail line runs almost parallel to the River Ganges between Haridwar and Raiwala town and then it turns towards Dehradun and runs parallel to river Song, a tributary of the River Ganges in this area. A total of 17 elephants has been killed in train accidents in this area. This rail line is passing through the narrow Chilla-Motichur corridor between place Motichur and Raiwala.

Road

Haridwar-Dehradun/Rishikesh Road

This is also situated on the West bank (right bank) of the River Ganges and is dividing the Park into two unequal halves. Initially, it was a forest road with low traffic, but now it is the important link route to the hilly area. This route is used by mixed traffic encompassing the tourists, pilgrims, governmental officials, and workers of hydroelectric irrigation projects, apart from the local public, around the clock. As per the latest observations (August 2001), the average number of vehicles passing on this road per day are 7,929 (1,972 heavy commercial vehicles; 3,957 passenger cars, and 2,000 motor bikes).

August is supposed to be a lean season, so the traffic in peak season will be more than the observed data. The road is running parallel to the rail line, approximately 100 to 120 m apart, between Motichur and Raiwala in a stretch of 3.0 km, in the Chilla- Motichur corridor area. Virtually all the wild animals, including elephants, are not in a position to cross this road at any time due to the presence of traffic around the clock.

Kotdwar-Lansdown Road

This road runs parallel to the River Kho and crosses the Rajaji-Corbett corridor, the main movement route of northwestern elephant population between the Yamuna and the river Sharda. This road serves as the main transport link between Pauri town and Kotdwar town (base rail station). The presence of traffic on the road, construction of steep retaining walls by the side of the road, and presence of human population along the entire corridor area have almost stopped the migration of herds using this corridor (Johnsingh and Williams 1999).

Hydro Electric and Irrigation Canal

A 14.0-km-long power canal of Chilla Hydroelectric Project of 20,000 cubic foot-per-second discharge capacity is situated on the East bank (left bank) of the river Ganges and almost runs parallel to the river. The canal is 12.5 m wide and 9.1 m deep, with cement concrete-tile-lined sides. Seven major cross drainage structures have been constructed at the junction of the canal and the torrent. The project was commissioned in 1982. The entire canal area is in the high intensity zone of Asian elephants.

An irrigation canal of Eastern Ganges Irrigation project of 4,850 cubic-foot-per-second discharge capacity is also a problematic engineering structure for the elephants. This canal is off taking from the left bank of Haridwar Barrage. The canal is 12.0 m wide, 4.5 m deep, and both of its side slopes are boulder pitched or cement concrete tile lined. The head reach of the canal is also a high intensity zone of elephants. There are many torrents in the area, which were frequently used by elephants as movement routes, have been

abandoned by them now due to construction of this canal. Due to construction of these canals on the East bank, the forest embankment of the Ganges has been reduced to 25 percent only.

Human Habitation – Biotic Pressure

Defense Camp and Tehri Dam Resettlement Colony

An area of 63 hectare of land was allotted to the defense department in 1963, and later an area of 43 hectare land was allotted to Tehri Dam Project for rehabilitation of the displaced people of Tehri Dam from elephant habitat in the Motichur range in the Chilla-Motichur corridor area. A considerable area of the forestland on the left bank of the Motichur torrent having thick forest, near the confluence with River Ganges has been washed away during frequent floods. These factors have reduced the width of the forest bank touching the River Ganges. So due to the lack of forest cushion and encroachment on the forestland, the movement of elephant herds from forest to river has almost been stopped. However, solitary bulls are still using the path to go to the river and Chilla forest.

Adjoining Human Population

The lower income groups of the adjoining human population of the Park are mostly dependent on the forest for their firewood and fodder requirement. At the same time their domestic cattle are also feeding inside the Park. The local labourers are also commercially exploiting the forest. They bring the firewood from the forest and sell it to the persons owing *ashrams* and hotels of the towns. These activities are also degrading the habitat.

Establishment of Ashrams and temples on the riverbanks

As per the Hindu mythology, the river Ganges is the most sacred river for the people. Therefore, most of the saints and Hindus try to live on the bank of Ganges near the Haridwar town. Many ashrams and temples have been constructed on the riverbank. These ashrams, temples, and other religious establishments/ buildings are crowded places and are highly illuminated during the night with a chanting of hymns. These factors have further added problems to movements of elephants.

Presence of Van Gujjars in the Park

The presence of Van Gujjars (migratory tribe) in Rajaji National Park is also creating problems to the elephants. These Van-Gujjars are living in the Park with their cattles (buffalos, goats, horses, etc). The forest provides fodder for their cattles, the firewood for them, and raw material for their temporary houses in the forest, locally known as dera. Van Gujjars lops the trees badly and in a very unscientific way, which affects the growth and the regeneration of the trees in the forest. The fodder trees are common for their cattle and the wild elephants. These Gujjars and their cattles are the biggest problem for the ecosystem of the Park.

Ethology of Asian Elephants

Territorial Behavior

The population of wild Asian elephants has a discontinuous distribution in the Northern, Eastern, and Southern ranges of India. In the past the elephant population of the North used to migrate freely from one end to the other from the River Yamuna to the River Brahmaputra, traveling a maximum distance of approximately 1,300 km as per their requirement in the foothills of Himalayas. All the major habitats of elephants are very close to perennial rivers that fulfill their water requirement, and the surrounding forests provide them fodder.

Elephants generally do not have a fixed territory, but they show various territorial behaviors according to the season and availability of natural fodder. It has been observed that whenever there is scarcity of water in the upper reaches of the habitat, the elephants try to move down the gradient along the torrents or natural depressions of the area in search of water. They have a feeling or instinct that these paths will take them to some water source (like any pond or river). This type of phenomenon is very common in the Rajaji National Park area, particularly between November to May every year, as this area is semi-hilly and has lots of torrents, which are mostly active during the rainy season and get dried during rest of the year. The elephants use these torrents as their pathway for movement.

Feeding Habits and Feeding Grounds

The elephant consumes 75 to 150 kg of food and 80 to 160 liters of water every day (Shoshani, 1992). Due to blockage of their movement routes with the presence of linear developments and developmental activities, the elephants are now forced to enter into human habitation in search of food. Mostly they are attracted towards the crops like sugarcane (February to June), paddy (September to December), and wheat (February to April), etc. (Singh 2001). Thus, they have developed a taste for this type of food, and now they are regularly raiding the crop fields of the villages in the adjoining areas. This has resulted in man-elephant conflicts. It has been observed that the elephants have become a regular visitor of these agro-fields of the farmers in the same season every year for eating the same variety of crops.

The feeding ground shows a great variance with respect to the seasons, elevation, and availability of water and fodder. They feed mostly *Mallotus philippensis*, *Ehretia laevis*, *Bridelia retusa*, *Ziziphus xylopirus*, *Acacia catechu*, *Ougeinia oojenensis*, and *Lannea coromandelica*. It has been observed that if there is any disturbance near the feeding ground, then only a solitary bull of few herds will dare to go to that area. Mostly the herd avoids such spots, even at the cost of traveling longer distances to get the same object elsewhere. As most part of this northwestern track comprises foothills, so they are well adapted to feed on these semi-hilly tracks.

Migration/Movement

The elephant is a long distance migratory animal. The purpose of this migration is to get water, fodder, and mating partners. Short distance migration also plays an important role, when there is scarcity of water in the upper reaches of forest, particularly from November to April every year. They stay in an area for a few days and then move to another area. They have a natural tendency to roam about freely for long distances. The migration of herds across these linear developments has almost stopped. However, bull elephants used to cross these artificial barriers created by the linear developments for meeting the mating partners. But this will also not last very long under the high pressure of developmental activities.

Parental Care

Parent care is well developed in elephants. It has been observed that the parents always protect their baby elephants. Babies are always allowed to move in the center of the herds. Mostly they move below the tummy of the mother. It has also been observed that the females are more attached to the baby elephants than the bulls. No doubt the bull is more offensive than the female during times of danger or attack. The bull takes care of females as well as babies.

Death of Elephants in Train Accidents

It has been pointed out earlier that the elephants have to visit the water spots daily for their drinking and bathing requirements, particularly between November to May every year. The elephants have to cross the rail track between Motichur to Kansaro for reaching the River Ganges or the Song - the perennial source of water in the western part of the forest in the Motichur-Kansaro range. There are five trains between 7:00 p.m. to 11:00 p.m. on the Haridwar-Dehradun rail track; incidentally, this is the time when the herd tries to cross the track for reaching the water spot.

All the major accidents took place during this time slot. Normally, the herd moves during night to avoid confrontation with human beings present in the area during the daytime. Normally, one would feel that any train could hit the elephant crossing the track, but it is not so. The reason for the accidents is different: on several occasions, when a herd is passing the track and meanwhile the train comes, under this situation, the members of the herd are divided into two groups by the moving trains. In the night this situation creates confusion in the members of the herd (particularly the mother) who thinks that the train has hit the babies and the other members of the group on the other side of the track because they are out of the sight. The infant tries to run towards the mother, and the mother towards the infant. All of this confusion, combined with the herd psychology and the bond between the calf and the mother, are the reasons for these accidents. This analogy is supported by the fact that either the infant is found dead or seen alive at the accident spot by the train driver. Most of the dead elephants are elder females and/or calves. In one accident (February 5, 2000), the dead elephant was a female and milk was also observed in her breasts.

Sometimes the elephants have to walk along the rail track in a zone having one steep hillside slope before ultimately crossing the rail line. In this zone, the elephants are trapped between the train and the hillside slope. The sudden arrival of train and the sound of its siren scare the elephants, and they are killed by collision.

Elephants' Reaction to the Existing Civil Engineering Structures

The elephants have used the torrents of the area as their paths of movement since time immemorial. And now structures have been erected/constructed at the junction of these torrents and linear developments, so there is a direct confrontation between the elephants and these structures. They try at their level to best adapt to these structures, if there is any possibility for their acceptance. Detailed observations of the authors regarding this situation follows.

- (1) On the adjoining roads where the traffic intensity is low, the elephants move up to the structure along the torrent and then cross the road from up or down side of the structure on the road, because the existing structures (road, causeway, or bridge) do not fulfill their requirement to get across.
- (2) If the herd is willing to cross the road, and if they feel any disturbance, first the head of the group, the bull tusker, will come on the road and will trumpet to terrorize the traffic and will stand on the road until the herd passes. In the normal routine, if some vehicle approaches during their crossing time, the members of the herd on both sides of the road will stand quietly but cautiously behind the adjoining trees. They will cross the road after the vehicle passes. This all is possible while the traffic intensity is low on the road. Until today, there has been no death of elephants in road accidents in this area. This type of phenomena is not possible in the case of trains because the moving trains are quite long.
- (3) The elephants of Rajaji National Park were natural visitors into the canal bed during the construction of the Chilla hydroelectric project canal, where the earthen embankments were negotiable, but after completion of the construction of the canal with cement concrete-tile-lined steep side slopes, the movement of elephants was completely obstructed.
- (4) There are two bridges on the Chilla canal for the inspection of the project. The elephants are also using these bridges to cross the canal. Currently, only solitary bulls are using both the bridges, but a few herds are using the Sonisot Bridge. It has been observed that the entry of the bull elephant is normal on the bridge, but when the elephant looks at the flowing water in the canal below him, then it moves quickly and crosses the bridge in a frightened condition. The probable reason for such a reaction is the vision of moving water below the bridge because such conditions do not exist in the elephants' natural environment.
- (5) The barrels of the cross drainage structures (Duggada Syphon) made on the canal for crossing the torrents are large in size. But the herds have not accepted these barrels to go across due to tunnel syndrome, in spite of the availability of sufficient water on the other side of the canal. Again, the bulls are using these structures.
- (6) The water tanks fed from canals are constructed on the forest side. These are good alternatives, and the herds are using them regularly from November to May every year. They are located very near to the canal inspection road, so there is lot of disturbance by the moving traffic on the road.
- (7) Boulder wire crates are used in the Park for river training works for guiding the water flow in the torrent/river. The edge of the wire crate/mesh generally pierces into the foot of the elephants when they move on the wire crates lying in the bed. The elephants avoid such routes on which such hurdles exist.
- (8) The cement concrete blocks are used as an energy dissipation device at the downstream end of the causeways or barrels of the super passages. These cement concrete blocks after launching create vertical drops of more than a meter. The herd cannot cross these vertical drops in the bed of the torrents. In such a situation, many torrents are abandoned by the elephants. The herds usually avoid such structures due to the safety of their younger ones.

Remedial Measure for Minimizing the Conflicts:

Measures Taken by the Government

Conservation of Asian elephants is the top priority of the government of India as well as state governments. A project is being implemented in which elephant reserves are being strengthened to prevent poaching of male elephants for their tusks. Elephants are notorious for crop raiding and damaging property as well as endangering human lives in some cases. The government of India and government of Uttaranchal are paying compensation for all sorts of damages. Elephant fencing and other barriers are installed to check elephants'

entry to adjoining local population areas. Corridors are being identified and efforts are being made to make them operational for the elephants' movements. The male-female ratio of northwestern elephant populations is around 1:2.2, which is highest in India; whereas in some south Indian states, this ratio has become critical with 1:100 or more. In Rajaji National Park, rehabilitation of Van Gujjars (Migratory tribe) is in process and likely to be completed in a year or so. The Uttaranchal government is trying hard to make a comprehensive plan for handling these problems by incorporating the suggestions of all related departments.

Role of Local People

Elephants are attracted to crops of wheat, paddy, and sugarcane of adjoining villages. These crops are cash crops, so the villagers are using fires, guns, and the drums to keep the elephants away. The process of paying compensation by the department is very lengthy and troublesome for the uneducated villagers (Badola 1998). Although they love the elephants, because the elephant is the member of the God family of Hindus- lord Shiva, the negative attitude is due to losses incurred from the crop raiding as well as losses to human lives and property. There is a tendency of local poor people or migrated poor people to occupy the forest/government land for making their temporary houses for their livelihood. This encroachment concept is very vital near the thin bands of migration/movement paths of elephants. The presence of the hutments and temples in the river bed on the left bank of river Ganges at Haridwar is a very good example of this encroachment. Due to the presence of local people in the area, the elephants are moving mostly in the night for crossing the man made impediments.

Practical Solution of the Conflict

Improved designs of the structures made on the road, rail line & canal

If the high-speed vehicles or trains are required to run on the road or rail line, then the entry of the elephants has to be restricted on the road or rail line with fencing and properly designed mitigation structures. Globally, this concept is in use, particularly in developed countries on express highways, and they have successfully managed this conflict by providing properly designed fences along the road and mitigation structures across the road. In cases of canals, where the side slopes are steep and cement concrete lined or boulder pitched, the mitigation structure is the only alternative. The cross drainage structure on the torrents should also be designed in such a way that it incorporates the requirements of the animals of the area to move across. The elephant can move across or enter into the earthen canal having flat side slopes with shallow water. In cases of tile-lined and steep side slopes, this is not possible.

For roads on which the traffic intensity is low, level crossings, such as causeways, are good alternatives to bridges. The only point that should be incorporated in the design is that there should not be any vertical drop in the bed of the structure along the torrent. The entire bed surface should be flat or having a moderate slope that the elephant can negotiate. It has been experienced that 1:4(V:H) is a good slope that the elephants can negotiate.

Alternate sources of water in the form of artificial water tanks is a good alternative. The elephants are using the existing water tanks fed from the Chilla power canal. The only point, which is very important, is that it should be inside the forest having sufficient forest cover. With this, elephants will not be disturbed by the moving traffic on the rail or road. The correct location of the water tanks will regulate the unwanted movements of elephants. They will not cross the impediment in case they get water on one side of the obstruction.

Construction of overpass and underpass as mitigation structure

It is the opinion of the author that the elephants will not accept an underpass because they are not used to living in such type of structures, not having a roof in their natural environment. The barrels of the Duggada aqueduct on the Chilla canal are proof of this case. The barrels are six in number and each 8.0 m wide and 6.0 m high. The project was commissioned in 1982, and today the herds have not accepted these barrels to move across. Although the structure is in a high intensity zone of elephants and there is lot of water on the other side of canal. Again, the lone bulls are using these barrels to across.

Properly designed overpasses can be a good alternate for the elephants for crossing the linear development. In case it is not possible to construct an overpass due to the topography and requirements of the structure, then

ecofriendly underpasses (aqueducts) with wide and ample headroom could be an alternative instead of small barrels.

For the construction of overpasses for the elephants, following criteria should be followed:

- (1) The structure should be 70-80 m wide at entry and exit point and 30-40 m wide at the top of structure to accommodate big herds.
- (2) The entry to exit ramp should not be steeper than 1:7 (V: H).
- (3) The sidewalls of the structure should be blind and a minimum of 3.5 m high so that moving traffic on the road or flowing water in the canal should not visually disturb them.
- (4) The sidewalls of the structure should be camouflaged and local vegetation should be planted in the bed of the structure so that it should look like an integral part of the forest. No tree in the alignment of the structure should be cut; rather it should be protected.
- (5) The fencing along the road or rail line should be such that it should not give barrier effect. 2.0-2.5 m high vertical poles of steel or old rails with proper spacing can be an alternate for the fencing.
- (6) The structure should be located along the established movement tract of the elephants so that they should not sense any problem with approaching the structure.
- (7) Some sort of attraction, such as a water tank or some likely type of fodder tree, should be planted near the entry and exit point of the structure.
- (8) Fresh droppings of elephants should be placed near the structure, whose smell will attract the elephants towards the structure.

If they use these structures once and they do not feel any problem, then they will use these structures regularly.

Safe Passage for Elephant's Migration - Temporary Closure of Traffic

The migration of elephants across the rail tracks and roads has a set pattern. The elephants start crossing these obstructions from November to May every year and daily in the night from 1900 hrs to 0500 hrs in the morning. So temporary closure of traffic on the roads and rescheduling of trains can be an alternate to avoid this conflict. In the present socio-political network, it is difficult to implement, but at least it can be tried on the experimental basis.

Conservation of Corridors Used by Elephants

The Chilla-Motichur corridor is facing many anthropogenic and natural problems. The width of the corridor is almost reduced to zero at the riverbank due to erosion of the left bank of the Motichur torrent near the confluence with the River Ganges. The encroachment of this habitat by the defense department, the settlement of the rehabilitated persons of Tehri Dam Project in the area, presence of the local population in the forest area for the want of firewood and fodder, the presence of roads and rail lines crossing the narrow corridor width having high density mixed traffic on it, and the presence of *ashrams* and other religious buildings on the river bank, are the main factors for the degradation of these corridors. The conservation plan of the corridor should incorporate in mitigating these problems.

Integrated Management of Linear Developments for Minimizing the Conflicts

For minimizing the man-elephant conflicts in the sub-Himalayan zone of Uttranchal, India, an integrated approach to management of linear developments in the area should be developed. Under the approach wildlife biologists, environmentalists, civil engineers, planners, social workers, prominent local inhabitants, road and railways staff, and government officials of central and state governments, including the forest department officials, should be involved. The intrigation of the viewpoints of all the groups should form the baseline for future development and conservation of elephants in the area. For this purpose, the obtained data related to man-elephant conflicts in India or elsewhere should also be kept in mind, while planning the activities in the area.

Conclusion

Studying and analyzing in depth the problem of conflicts between the Asian elephants and the linear developments in Rajaji National Park, it has been concluded that the linear developments, mainly rail lines, roads, and hydroelectric and irrigation canals, are contributing substantially to the fragmentation of elephant habitat in the area. The remedial measures for minimizing the conflicts and construction of mitigating

structures like overpasses and underpasses in the area should be undertaken, keeping in mind the ethology (territorial behavior, feeding and mating behavior, migration, and parental care instinct, etc.) of the Asian elephants for ensuring the sustainability of the north western elephant population of the area. To combat the problem of the existing civil engineering structures present in the park, which are not suitable to the elephants, the structures should be modified to desired extent with minimum input of time. It should also be kept in mind while initiating any linear developments in the area that they should not damage or contribute to the deterioration of the ecosystem.

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