Library Progress International
Vol.44 No.3, Jul-Dec 2024: P. 27086-27095

Print version ISSN 0970 1052
Online version ISSN 2320

Original Article

Available online at www.bpasjournals.com

Elephant Migration in Eastern Maharashtra: A Thermal Drone Approach to Wildlife Tracking

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How to cite this article: Kakavipure Dilip K., Dhananjay Kundlik Waybhase, Akshay Laxman Patil(2024) Elephant Migration in Eastern Maharashtra: A Thermal Drone Approach to Wildlife Tracking. *Library Progress International,* 44(3), 27086-27095

Abstract:
Animal migrations are dynamic phenomena that vary over space and time, even among closely related species, populations, and individuals. For example, in many animals there is substantial geographic variation in the migratory tendencies of different subspecies, races, or populations—birds that breed in the north may migrate long distances south to spend the winter, whereas members of the same species that breed at lower latitudes may be entirely sedentary (i.e., non-migratory). Further, even within a discrete population, there can be systematic differences in the distance, routes, endpoints, or seasonal timing of migrations among male versus female or younger versus older individuals. Such variation in migratory behaviours can emerge rapidly over "evolutionary time scales" (e.g., thousands of years)— including over contemporary times (e.g., years or decades) in response to human activities such as habitat alteration and climate change. We know that elephants are more than mentally capable of migrating, but what initiates this travel? One cause for elephant herds' migration is the dry season's search for food. Elephant herds can have up to 100 individuals who must all eat to survive. Elephants can be incredibly aggressive towards humans in a variety of circumstances. Apart from male elephants during must, female elephants may become more aggressive after giving birth or having a calf born within the herd. Elephants are naturally peaceful creatures, but they may get violent under certain circumstances. For instance, mother elephants may aggressively defend their young when they are threatened. Furthermore, when asserting their dominance, male elephants can be hostile. Throughout Asia and Africa, crop raiding has become a severe problem for many farmers. Elephant herds come to villages and eat and stomp on crops leading to severe damage to villagers and farmers. This has become such a significant problem throughout elephant territories that throughout 1997 450,000 square meters of cropland were damaged or destroyed by elephant herds. Data for this article were obtained from field studies (since 2020-2023) aimed at a broader survey of wildlife in general in different areas of Maharashtra India. In this study we provide results from a thermal infrared and Red Green Blue (RGB) survey of migration of elephants in the Gadchiroli area of Maharashtra. The survey was undertaken using a UAV equipped with a point and shoot digital camera for standard visible images (RGB), and a thermal infrared camera.

Key points: Thermal infrared, Red Green Blue (RGB), UAV, Digital camera, Thermal infrared camera, non-migratory, sedentary, migrations, photogrammetry, global positioning, dwindle.

Introduction:
Animal migrations are dynamic phenomena that vary over space and time, even among closely related species, populations, and individuals. For example, in many animals there is substantial geographic variation in the migratory tendencies of different subspecies, races, or populations—birds that breed in the north may migrate long distances south to spend the winter, whereas members of the same species that breed at lower latitudes may be entirely sedentary (i.e., non-migratory). Further, even within a discrete population, there can be systematic

differences in the distance, routes, endpoints, or seasonal timing of migrations among male versus female or younger versus older individuals. Such variation in migratory behaviours can emerge rapidly over "evolutionary time scales" (e.g., thousands of years)— including over contemporary times (e.g., years or decades) in response to human activities such as habitat alteration and climate change. Therefore, effective conservation agendas for animal migrations must consider the implications of both spatial and temporal variation in migratory behaviour, even within a single "migratory species" or a single local population. Elephants travel thousands of miles in their lives, constantly moving in herds. But how do they know where to go? Elephants are among the most intelligent species in the world and have the largest brain among land animals, allowing them to store complex information about their surrounding environment.

Photogrammetry is a technology that allows the reconstruction of three dimensional information (i.e. Digital Elevation Models) from a mosaic of overlapping, two dimensional photographs (Westoby et al., 2012). Although photogrammetry is not a new technology, recent advances in Unmanned Aerial Vehicle (UAV or drones) equipped with global positioning systems (GPS) and digital cameras have reduced the cost of collecting imagery. Modern desktop and cloud computing power allows for routine post processing of large numbers of individual image photos. Lightweight thermal sensors provide another payload option for generation of very high resolution aerial thermal Ortho photos. This technology promises to allow the rapid and safe survey of thermal areas, often present in inaccessible or dangerous terrain.

In this study we provide results from a thermal infrared and Red Green Blue (RGB) survey of migration of elephants in the Gadchiroli area of Maharashtra. The survey was undertaken using a UAV equipped with a point and shoot digital camera for standard visible images (RGB), and a thermal infrared camera. Elephants are commonly known to be migratory animals. They travel thousands of miles for many motives. This extreme travel also can influence the species around them. Such as highly disrupting human settlements and changing food availability for other species. However, what triggers this decision? What prompts an elephant herd to embark on such an arduous and long journey? Prior investigation reveals that elephants move by choice rather than innate response. Knowing this, the idea of involuntary migration does not describe elephants because involuntary migration is an innate animal instinct. So, if elephants do not migrate innately, why do they choose to migrate, and how does elephant migration affect neighbouring species? Elephants are facultative migratory and migrate in response to both artificial and natural triggers, and this travel significantly affects adjacent environments in several ways.

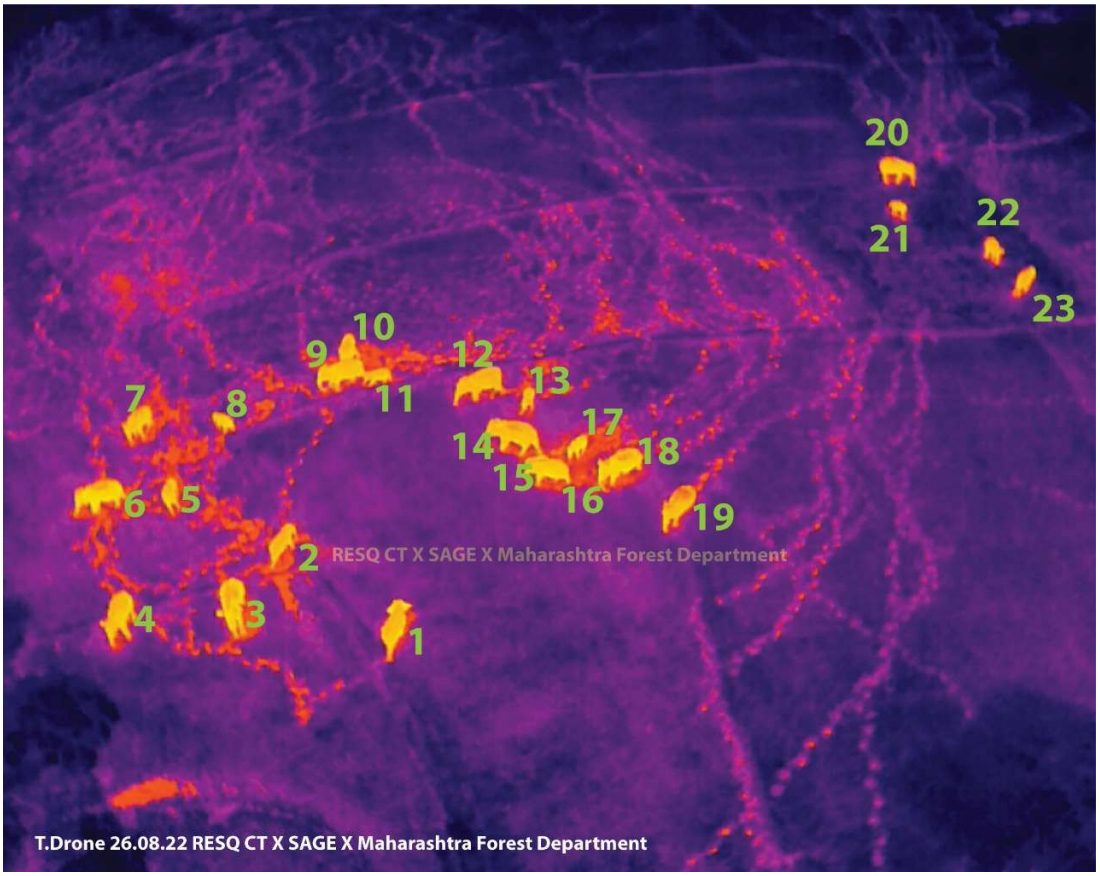
Methods:

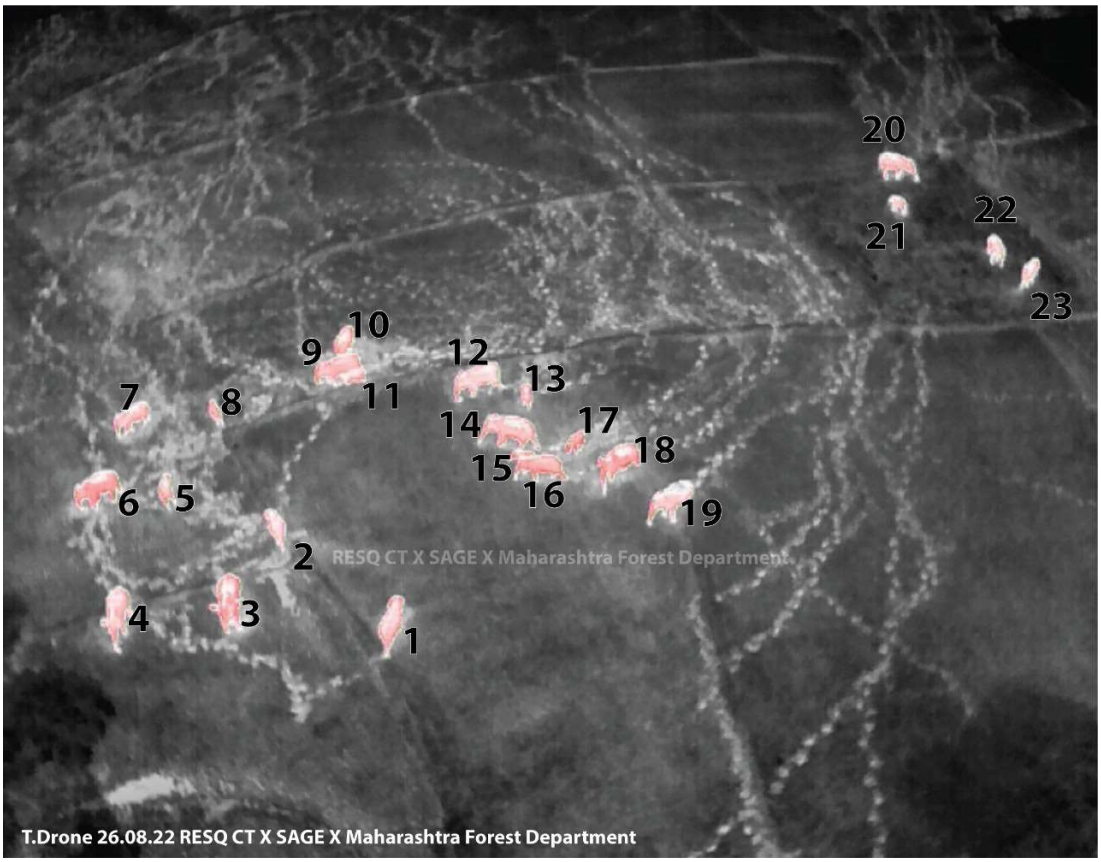
Data for this article were obtained from field studies (since 2020-2023) aimed at a broader survey of wildlife in general in different areas of Maharashtra India. These studies examined the presence, distribution, and status of different species of wildlife, especially elephants. The fieldwork also recorded conflicts between humans and elephants. Effort was made to interview the villagers, forest staff, and hunters/ poachers that had experienced conflicts with elephants.

Wadsa Division - Wildlife Elephant Herd Tracking									
Sr	**Date**	**Incident Type**	**GPS Coordinates**	**Range**	**Compt. No.**	**Closest Village**	**Time of Incident**	**Source**	**Notes**
1	14/08/2022	Crop Damage	20°28'35.0"N 80°28'22.0"E		370	Kumudpur		Forest Dept	
2	14/08/2022	Crop Damage	20°28'26.0"N 80°27'07.0"E	Malewada	1247	Huryaldand		Forest Dept	
3	15/08/2022	Structure Damaged	20°28'11.0"N 80°26'18.0"E	Malewada	355	Huryaldand		Forest Dept	
4	15/08/2022	Crop Damage	20°28'38.0"N 80°25'14.0"E	Malewada	354	Huryaldand		Forest Dept	
5	16/08/2022	Structure Damaged	20°27'17.0"N 80°23'39.0"E	Malewada	350	Waghbhumi		Forest Dept	
6	20/08/2022		20°28'10.0"N 80°26'24.0"E	Malewada	355	Kondekanher		Forest Dept	

7	21/08/2022		20°28'22.0"N 80°22'36.0"E	Malewada	350	Waghbhumi		Forest Dept	
8	22/08/2022	Crop Damage	20°28'19.0"N 80°22'34.0"E	Malewada	350	Jaisinghtola		Forest Dept	
9	22/08/2022	Crop Damage	20°28'07.0"N 80°22'23.0"E	Malewada	1236	Jaisinghtola		Forest Dept	
10	22/08/2022	Crop Damage	20°28'22.0"N 80°22'47.0"E	Malewada	1237	Jaisinghtola		Forest Dept	
11	23/08/2022		20°27'34.0"N 80°23'29.0"E	Malewada	350	Waghbhumi		Forest Dept	
12	23/08/2022		20°27'51.0"N 80°23'52.0"E	Malewada	349	Waghbhumi		Forest Dept	
13	24/08/2022	Crop Damage	20°27'37.0"N 80°23'40.0"E	Malewada	350	Waghbhumi		Forest Dept	
14	24/08/2022	Crop Damage	20°27'55.0"N 80°23'56.0"E	Malewada	349	Waghbhumi		Forest Dept	
15	25/08/2022	Crop Damage	20°28'42.0"N 80°23'19.0"E	Malewada	350	Waghbhumi		Forest Dept	
16	25/08/2022	Crop Damage	20°28'54.0"N 80°23'22.0"E	Malewada	351	Waghbhumi		Forest Dept	
17	26/08/2022	Dung Present	20°28'45.0"N 80°32'28.0"E	Malewada	350	Waghbhumi		Forest Dept	
18	27/08/2022	Crop Damage	20°28'50.0"N 80°23'40.0"E	Malewada	350	Updalli		Forest Dept	
19	31/08/2022		20°29'42.0"N 80°29'49.0"E	Malewada	371			Forest Dept	
20	01/09/2022	Structure Damaged	20°29'42.0"N 80°29'49.0"E	Malewada	371	Gangasaytola		Forest Dept	
21	02/09/2022		20°29'46.0"N 80°29'50.0"E	Malewada	371	Gangasaytola		Forest Dept	
22	03/09/2022		20°29'48.0"N 80°29'40.0"E	Malewada	371	Gangasaytola		Forest Dept	
23	04/09/2022		20°29'36.0"N 80°29'49.0"E	Malewada	371	Gangasaytola		Forest Dept	
24	05/09/2022	Crop Damage	20°28'28.0"N 80°27'02.0"E	Malewada	1247	Huryaldand		Forest Dept	
25	06/09/2022	Crop Damage	20°30'01.0"N 80°26'38.0"E	Malewada	358	Yedsukhi		Forest Dept	
26	07/09/2022	Crop Damage	20°31'23.0"N 80°26'21.0"E	Malewada	360	Khobramendha		Forest Dept	
27	08/09/2022		20°31'36.4"N 80°25'32.3"E	Malewada				RESQ	
28	10/09/2022		20°35'04.4"N 80°20'55.7"E	Purada		Dadapur		RESQ	
29	10/09/2022		20°34'49.6"N 80°20'50.0"E	Purada		Dadapur		RESQ	
	11/09/2022		20°34'49.6"N 80°20'50.0"E	Purada		Dadapur		RESQ	
	12/09/2022		20°34'49.6"N	Purada		Dadapur		RESQ	

			80°20'50.0"E						
	13/09/2022		20°34'49.6"N 80°20'50.0"E	Purada		Dadapur		RESQ	
	14/09/2022		20°33'57.6"N 80°14'15.1"E	Delanwadi	286	Shivani		Forest Dept	
	15/09/2022		20°33'57.6"N 80°14'15.1"E	Delanwadi	273	Sonsari		Forest Dept	
	16/09/2022		20°33'44.7"N 80°12'56.9"E	Kurkheda		Chandagad		Forest Dept	
	17/09/2022 18/09/2022		20°34'21.4"N 80°11'12.5"E 20°36'08.8"N 80°10'34.2"E	Kurkheda Kurkheda		Khairi Wagheda		Forest Dept Forest Dept	
	19/09/2023		20°36'08.8"N 80°10'34.2"E	Kurkheda		Wagheda		Forest Dept	
	20/09/2023 21/09/2022		20°36'08.8"N 80°10'34.2"E 20°38'42.9"N 80°07'25.4"E	Kurkheda Kurkheda		Wagheda Khedegaon		Forest Dept Forest Dept	
	22/09/2022		No location yet	Wadsa		Wadsa		Forest Dept	
	24/09/2022		20°42'15.1"N 80°03'35.1"E						





Result and discussion:

How Do Elephants Migrate?

Elephants travel thousands of miles in their lives, constantly moving in herds. But how do they know where to go? Elephants are among the most intelligent species in the world and have the largest brain among land animals, allowing them to store complex information about their surrounding environment. They use this cognitive ability to learn complicated migratory routes throughout the decades of their lives. This cognitive mapping ability in elephants has been compared with primates and shows the sheer extent of the elephant brain. Through extensive research on primates, researchers have concluded that they can compute the locations of fruit trees and other food sources within a limited space. This ability was thought to be severely impressive, seeing that not many species can map out their surroundings to this extent. Still, this information also only lasts in their brains for a couple of years before they forget and must relearn their surroundings. This cognitive ability, compared to an elephant's cognition, is stunning. Both African and Asian elephants can navigate and map paths for vast distances of thousands of miles and remember locations of important places such as water holes, food sources, and the whereabouts of their extended family. This information is not only highly accurate; it lasts for the entire lifespan of an elephant and then passes it down to its children through years of traveling the same paths and learning as they go. This mental navigation ability allows elephants to access necessities at any time in their lives. This comparison is significant because primates are considered complex and intellectual animals, but elephants are more perceptive in many aspects of mental cognition. The mental capacity elephants possess demonstrates just how intelligent they really are. Researchers frequently discuss primate cognition but often seem to forget the cognitive skills of elephants. This incredible aptitude is what makes studying elephant migration so important. It serves as a means to explore animal intellect at a previously impossible rate. By exploring elephants' intricate memories and mapping their migratory paths, we can better understand how intellectual animals like elephants can really be. A study that was conducted in 2007 revealed that elephants could track and differentiate their relatives based on the scent of their urine droppings. This study explored how elephants would react to urine samples from different sources. Researchers discovered that the elephants were most interested in their own relative's urine over that of samples from random elephants. They are able to use this ability to track up to thirty

of their family members at the same time. This ability allows them to strengthen their migratory paths as they follow the scent of their relatives and leave their urine on the track, which continues the cycle, leaving a new track for future elephant herds to follow. A further demonstration of elephant memory is how elephant herds with older matriarchs survive longer during a drought. This demonstration is significant because it exemplifies the extent of elephant memory because these older matriarchs can harness decades-old information about water holes to lead their herd to survive. This incredible skill demonstrates how extraordinary the elephant brain is and how the unique mental cognition that elephants possess allows them to travel thousands of miles whenever needed efficiently.

What Triggers an Elephant to Migrate?

Search for Quality Nutrition:

We know that elephants are more than mentally capable of migrating, but what initiates this travel? One cause for elephant herds' migration is the dry season's search for food. Elephant herds can have up to 100 individuals who must all eat to survive. As the dry season progresses, food and water start to dwindle. The herd's matriarch will pick up on this phenomenon and initiate migration in search of better food. This behaviour is seen in many herds and is more frequent during years with a longer duration of the dry season. This is prevalent as the longer the dry season continues; the food quality continues to worsen. This is why the herds travel most during prolonged dry seasons and rest the most during the wet season when food is abundant. The trend of migratory activity rising during the dry season displays how elephant herds strategically use migration and information about previously found food sources to survive during the difficult periods of drought. This strategy that elephants use to migrate makes elephant migration so unique. Many species of animals migrate regardless of the condition of their surroundings, even migrating when it is not very necessary. Here is where elephants are special. They can use migration in a way that is always efficient and takes their surrounding environment into account before setting out on such an extreme journey.

Search for Water:

In addition to food, elephants also require a fresh water source once their current source is thoroughly exhausted. As mentioned, water availability and rainfall patterns highly affect elephant movement. In fact, a study conducted in 1980 showed that herds move up to 6 kilometres a day in the absence of water sources and only 3 kilometres when water is abundant. These findings give an idea of how elephants take their surroundings into account and how the availability of water can drastically affect their movement daily. Throughout the same study, artificial water holes were placed sporadically near elephant paths to observe how they would affect the herd's path. The results showed drastic changes in the courses of the elephants due to the water sources and a drastically higher number of elephants in locations with more water holes. This finding also demonstrates the risk that elephants take when migrating. Many times, water holes that were full during the previous trips can be depleted and empty by the time the herd reaches them again. This can be dangerous as elephant herds can die due to dehydration if they continue to encounter empty water holes during their migratory periods. Overall, this displays that elephant movement is highly affected by water availability.

Avoidance of Predators:

Another reason elephant may migrate is that they are often preyed on by animals such as Lions and Hyenas. These animals are faster and stronger than a single elephant. Therefore, elephants try to avoid them as much as possible. The most common way herds avoid elephants is through their sense of smell. As previously mentioned, elephants are able to locate their extended family through the scent of their urine, but this is not all they can do with their sense of smell. Elephants can not only sense the presence of their family but also that of a predator through the scent of their excretion and will then alert the rest of the herd of the danger. Several researchers have observed this behaviour in the wild and have found a way to use this ability of elephants to keep them out of villages and farms. It has been proven to be the best method to safely keep elephant herds out of a particular area where they are prohibited. The villagers take the excretion of lions and hyenas and spread them around their villages. The herds are so cautious that they will remember where they smelt the predator dung and avoid that area in future trips. The herd's Matriarch remembers the locations of several predators in times of migration and constantly navigates to prevent potential threats and predators during periods of extended travel.

Habitat Loss:

Another threat posed to elephants is habitat loss and poaching. Elephants are consistently being driven out of their migratory land and constricted to limited land for movement and migration. An ideal example of this is the human-elephant conflict problem that arises in India. During the 1980s, forest cover drastically dropped to 30-40% forcing elephants into human settlements and causing problems. This is a significant problem because elephants are exposed to many threats, such as poachers, without the coverage of trees. Settlers replaced the previously forested land with agriculture. This quickly became another issue as elephant herds tried to continue their earlier migratory paths, which became infested with farms. The elephants would raid these farms of their crops and leave farmers distraught. The farmers combated this with several techniques to keep herds off crops. These methods, such as chilies, would drive elephants away but would leave elephants constrained to minimal space to move. The rising agricultural land drove the elephants further and further away from the land they had been traveling on for decades, severely altered elephant trails, and left decades of navigation by matriarchs useless, as settlements, villages, and crops cut off earlier paths.

Communication Through Seismic Vibration:

Another way that elephants can avoid potential threats and predators during their migratory periods is through seismic communication. Elephants are able to communicate with each other across hundreds of miles through seismic communication. This is the ability to communicate utilizing seismic vibration. They are able to do this by stomping their foot, creating a vibration that travels to the receiving elephant. This is possible due to two exceptional features of the elephant's body. The first is the elephant ears; elephant ears are the lowest frequency ear among land mammals. This means they can hear exceptionally low frequencies, such as the sound of a stomp traveling through the ground. The second feature is their susceptible foot pads. Due to their sensitive foot pads, elephants can not only hear these stomps but also feel them through the ground. Researchers have studied this ability by playing low-frequency acoustic sounds through the ground far away from a herd of elephants. They then repeated this for a few months to be able to form a concrete conclusion about the herds' behaviour. The elephant herd responded to these sounds by immediately leaving the area and running away. This reaction shows that the elephant herd perceived the sound/vibration as a warning of danger. This demonstration proves that elephants can perceive these sounds and react to them quickly. This ability allows elephants to warn each other about potential threats while migrating and allows elephants to communicate their location to each other as the receiving elephant can estimate the distance of where the sound came from. This also serves as another way that elephants can locate each other. As elephants are able to estimate the location of where a stomp came from, they can use that information to locate their family through seismic vibrations.

Migration Effects On the Surrounding Environment:

Humans and elephants co-evolved in Africa from earlier species. Humans have always lived alongside these amazing beings, and we share much in common with them. Both elephant and human young take a long time to mature. Both share complex social networks. an elephant does attack-charge you, it will use its tusks to gore you, throw you and crush you. It will often keep stomping until you're dead. Since elephants can blow down trees, flip cars, and run up to 40km an hour, you have little chance of outrunning them.

To tackle such conflicts and avoid losses on both sides, it is important to strengthen the humanelephant coexistence through by active management interventions by the State Forest Departments, involvement of various stakeholders and sensitization and generating awareness in local communities of forest fringe areas.

Are elephants aggressive towards humans?

Elephants can be incredibly aggressive towards humans in a variety of circumstances. Apart from male elephants during must, female elephants may become more aggressive after giving birth or having a calf born within the herd. Elephants are naturally peaceful creatures, but they may get violent under certain circumstances. For instance, mother elephants may aggressively defend their young when they are threatened. Furthermore, when asserting their dominance, male elephants can be hostile.

Effects on Vegetation:

As elephant herds migrate, they require a significant amount of food to fuel a day of trekking through harsh environments. A single elephant can consume up to 300 pounds of food in one day. The problem arises when herds of 10-20 elephants migrate together and feed on vegetation simultaneously. This can cause severe issues to protected land as elephants can quickly work their way through hundreds of trees with their extreme feeding habits during migratory periods. Many environments cannot support this excessive feeding, resulting in hundreds of dead trees caused by elephants feeding in sensitive protected areas. Several herds of elephants passed through farm lands, leaving the vegetation and trees in a horrible mess. Ninety-seven percent of the park's trees were left damaged or killed by herds, with 44 percent of the trees completely dead. This shows the severe impact elephant herds can have on a sensitive environment. Without proper precautions taken, elephant groups can highly damage areas of vegetation throughout their periods of migration. This affects not only the trees but also the other animals that live in that area. Without trees, many animals lose their homes and are left with nowhere to live. This is not the only case of vegetation destroyed by elephants; another sample of this occurred in Ruaha national park in Tanzania. Here, Elephants were a leading cause of tree density depleting year after year. As the elephant population rose, an increased number of trees were dying and damaged. Not only did the elephants damage the trees, but they also preferred the younger saplings of the trees. The research displayed that the elephants consumed more of the sapling trees throughout their stay in the park. This behaviour is even worse for the environment. Though consuming adult trees does damage the environment, consuming saplings can ensure that the environment will never be able to recover from the damage. This is because if the saplings are damaged, that destroys the next generation of trees, leaving no hope for the growth of the protected land. These parks and their tree systems are home to several species, and the effects of the elephants' feeding can cause the uprooting of these animals and leave them with no home. These effects of elephants can be hazardous to environments and, if not controlled, could kill foliage and demolish environments containing hundreds of varying animals.

Effects on Crops:

Another effect elephant has on the environment during migratory periods is crop raiding. Throughout Asia and Africa, crop raiding has become a severe problem for many farmers. Elephant herds come to villages and eat and stomp on crops leading to severe damage to villagers and farmers. This has become such a significant problem throughout elephant territories that throughout 1997 450,000 square meters of cropland were damaged or destroyed by elephant herds. This number of damaged crops can leave many villages starving and may lead to the deaths of many villagers. The damage significantly increased during the dry season, when elephants travel and eat as much as possible. Villagers took many different approaches to keep elephants away from crops and villages. One of the methods to deter elephants is a chili border around crops and villages. This border of ground chilis deters elephants because the chilis contain a pungent smell that is not palpable to elephants. Another method used to prevent elephants is elephant trenches. Deep trenches form a border around crops to stop elephants from entering. These deter elephants because they cannot escape the deep trenches and therefore stay away from them altogether. These extreme methods reveal just how significant the problem of crop raiding has become in elephant territories and, if not stopped, could leave villages distraught.

Conclusion:

Elephant migration that was previously considered an obligatory behaviour has now proven false. This extended travel may also have severe adverse environmental effects, such as damaging vegetation and village crops. The research analysed within this paper displays how elephants have extraordinarily complex minds and how natural and artificial aspects trigger their migration. These triggers include searching for nutrition and water, avoiding predators, and habitat loss. This induced migration causes many harmful effects to the surrounding environment through vegetation and habitat destruction due to the elephants disrupting these territories. In conclusion, elephants can be triggered to migrate in several diverse ways, and this extended travel can destroy foliage and cause a loss of habitat for several neighboring species.

Recommendations:

1. The following recommendations are offered for mitigating human–elephant conflict in North Maharashtra. First, new protected areas need to be created. With only about 25% of the habitat of elephants within

protected areas, there is an urgent need to create more protected areas. Although declaring an area as "protected" is not enough, it does offer a vital legal step toward conservation and reducing conflicts.

2. Second, wherever possible, the existing protected areas should also be enlarged and fragmentation of protected areas should be discouraged. Third, elephant migration corridors should be legally protected.
3. Corridors used regularly by the elephants should be given legal protection. This is important because it is highly unlikely that all of the corridors will be combined into national parks or sanctuaries.
4. Legal status should be granted in the form of a wildlife sanctuary where the corridors transect forestland. Problems arise, however, when corridors transect tea plantations, shifting cultivations, and human villages.
5. Humans and elephants are mainly in direct conflict in villages. Conflict is less of a problem in other corridor areas because elephants usually migrate at night. It is recommended that provisions for "protected elephant movement corridors" be amended to the Indian Wildlife Protection Act. At tea estates and areas of shifting cultivation, the land should continue to be managed by the private owners, but the amendment would ensure that land-use changes do not occur in the corridors.
6. At other places, the government can acquire strips of land under the Land Acquisition Acts and pay suitable compensation. Fourth, poaching wildlife for trade and meat consumption should be strictly monitored. Anti-poaching staff need to be better trained and equipped, and penalties for poaching should be more severe. In addition, all unlicensed arms should be confiscated. Fifth, shifting cultivation needs to be controlled/regulated.
7. Although it is unlikely that this practice will completely stop, as it is a deeply ingrained lifestyle Human–Elephant Conflicts in Eastern Maharashtra and culture, measures should be taken to control it, especially near prime wildlife habitat and migration routes.
8. Sixth, encroachment should be strictly monitored. New encroachments should be discouraged or banned, especially in the reserve forestlands. Recent encroachments such as those within elephant habitat (e.g., Nambor and Balipara forests in Assam) should be evicted and restored.

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