Movements of satellite-linked collared elephants and other wildlife in relation to the Standard Gauge Railway (SGR) and highways in Tsavo ecosystem, Kenya

(March – September 2016)

SAVE THE ELEPHANTS
拯救大象

www.savetheelephants.org

KENYA WILDLIFE SERVICE

www.kws.go.ke

Cover photo: An aerial view of the Tsavo River super bridge along the SGR that could also be used by wildlife as an underpass. Next to it is the Mombasa - Nairobi highway. A wildlife overpass to allow animals to crossing the highway needs to be urgently considered. *Photo courtesy of Richard Moller of Tsavo Trust.*

Suggested citation:

Okita-Ouma B., Lala F., Koskei M., Mwazo A., Kibara D., King L., Kanga E. & Douglas-Hamilton I. 2016. Movements of satellite-linked collared elephants and other wildlife in relation to the Standard Gauge Railway (SGR) and highways in Tsavo Ecosystem, Kenya (March – September 2016). Pages 1-34. Save The Elephants and Kenya Wildlife Service, Nairobi.

Authors' affiliations and experience

Benson Okita-Ouma, PhD., MBS.
Head of Monitoring and Research operations at Save the Elephants, with 20 years of experience in research and conservation of rhinos and elephants.

Fredrick Lala, MSc.
The Senior Scientist of KWS in Tsavo Conservation Area that covers Tsavo East, Tsavo West and Chyulu National Parks with more than 10 years of experience in wildlife conservation and research.

Michael Koskei, MSc.
Research Assistant at Save The Elephants with 5 years of experience and Geographical Information Systems (GIS) & Remote sensing.

Alex Mwazo, MSc.
Assistant Research Scientist at KWS based in Tsavo East National Park with over 5 years of experience in wildlife research.

Dennis Kibara, BSc.
Assistant Research Scientist at KWS based in Tsavo East National Park with over 3 years of experience in wildlife research.

Lucy E. King, DPhil.
Head of Human-Elephant Co-Existence Program and Elephants and Bees Project at Save the Elephants. She is a Research Associate with the Department of Zoology at University of Oxford in the UK with more than 10 years of experience in conservation and elephant research.

Erustus Kanga, PhD.
Senior Assistant Director for Biodiversity Research & Monitoring at KWS, with over 20 years of experience in biodiversity and natural resources management and ecosystems research.

Iain Douglas-Hamilton, DPhil., CBE.
The Founder and the Chief Executive Officer of Save the Elephants. Research Associate with the Department of Zoology at University of Oxford with over 50 years of experience in conservation and elephant research.

Contents

Introduction and background

This joint report by Save the Elephants and Kenya Wildlife Service summarizes preliminary findings of a long-term study on the effects of the Standard Gauge Railway (SGR), the Mombasa - Nairobi highway, the Voi - Taveta highway and other infrastructural developments on elephant movements and ecosystem connectivity in the Tsavo ecosystem. The extent of the utilization of the wildlife crossing structures, examples of exceptional elephant movements, the effect of water distribution on elephant movements, the effects of a recently constructed fence-line along the SGR are assessed and reported on here. The report concludes by listing several management recommendations. The study began in March 2016 when 10 elephants were fitted with satellite tracking collars for monitoring their movements in relation to these new infrastructure projects. Three months later, from June 2016, the study also began monitoring all wildlife activities through direct movement signs/tracks along the SGR. To the knowledge of the authors such a study has been conducted in Kenya or elsewhere in Africa. This study is essential because major infrastructural developments (such as the SGR and multi-lane highways) are a priority for governments across the continent but can restrict or prevent wildlife movement, often with negative consequences. Wildlife-crossing structures, underpasses and "fauna passages" remain the best tools for sustaining wildlife populations and maintaining landscape and ecosystem connectivity in areas affected by such mega developments. This report provides visual and quantitative data to help foster collaborative improvements in the Tsavo ecosystem. It provides a reference for good practice for future designs and placements of wildlife-crossing-structures that are compatible with wildlife conservation and ecosystem connectivity.

In 2014 the Kenyan government initiated construction of a 500 km Standard Gauge Railway (SGR) from Mombasa to Nairobi. This is one of the flagship projects under Kenya's development blue print Vision 2030, whose goal is to transform Kenya into a middle-income industrialized economy by 2030. This SGR is the most important transport project in Kenya since the building of the first Mombasa - Nairobi railway in the early 20th century. The SGR bisects the 23,000 km^2 Tsavo ecosystem comprising Tsavo East and Tsavo West National Parks. This ecosystem is home to many mammalian species including the country's largest single elephant population estimated to be between 12,000 and 14,000 animals. Some sections of the SGR are elevated more than 10 meters above the ground to minimize the gradient for high speed trains. A game proof electric fence is under construction on both sides of the approximately 135 km section that bisects the Tsavo Parks to prevent wildlife from approaching the tracks. Alongside the SGR is also the Mombasa - Nairobi highway that has been earmarked for expansion in the near

future. Additionally, inside Tsavo West National Park is the Voi - Taveta tarmac highway which cuts through the park in the middle from east to west. It is critical that appropriate crossings be incorporated into planning for the development of these roads, for safety and ecosystem connectivity.

It was feared that the SGR would cut the wildlife populations in two. However, the contractor of the SGR, the China Communications Construction Company Limited in collaboration with KWS, constructed six wildlife-crossing structures in the form of underpasses each measuring around 70 m long x 6 m high. The placement, design and sizes was guided by the long-term monitoring data and information generated by KWS. Other potential underpasses along the SGR are the 1,980 m long Tsavo River bridge, the 520 m long inter-crossing between the old railway and the new SGR at Kenani, and 30 drainages or culverts over seasonal dry riverbeds (luggas) that are greater than 5 m high and range from 6 m to 210 m long (Plate 1). Speed bumps and speed limit signage for wildlife-crossing have been provided at 4 sites along the Voi - Taveta highway.

(a)

Credit: Fredrick Lala, KWS 2016

(b)

Credit: Michael Koskei, STE 2016

(c)

Credit: Richard Moller, T.T. 2015

Plate 1: Example of (a) an underpass on an elevated railway, (b) a culvert which could be used as an underpass for elephants (c) an aerial view of locations of underpasses and culverts (white patch) along the SGR under construction. To the left of the SGR construction is the Mombasa–Nairobi highway and to the right is the old railway line.

Collared elephants and other wildlife crossing the SGR

Five female and 5 male elephants were fitted with satellite radio tracking collars within 20 km on either side of the SGR or the Voi - Taveta highway (Figure 1) between 15th and 17th March 2016. Selection of target animals, ranging distance and period of capture were aimed at maximizing opportunities for studying behavior and the influence of infrastructure, food and water on elephant movements.

Save the Elephants in partnership with Kenya Wildlife Service (KWS), Tsavo Trust and Wildlife Works have been monitoring the movements of the collared elephants daily. The 135 km section of the standard gauge railway between Bachuma and Mtito Andei is also being monitored for tracks of elephants and other wildlife species along its length. The monitoring has five aims:

(1) assess the effectiveness and utility of the underpasses along the SGR and speed bumps along the Voi - Taveta highway.
(2) discern the SGR, the highway and landscape properties associated with different elephant behaviors.
(3) understand potential impact of the SGR and the Voi - Taveta highway on the use of space and vital resources by elephants.
(4) provide quantifiable data to inform decision making in future infrastructural developments particularly the fencing design of the SGR and planning for wildlife crossings in any prospective development of the Mombasa - Nairobi highway.
(5) Quantify cost-effectiveness of the underpasses in terms of their frequency and design in reducing rail and road kills.

Long term data is still being collected to address most of these objectives. However, here we report on preliminary results of six months of tracking collared elephants and three months of monitoring other wildlife crossing the SGR. The results are aimed at sensitizing the relevant stakeholders on the effects of transport infrastructure on wildlife movements and ecosystem connectivity. We hope that both these results and future data will inform the ongoing and future infrastructural planning and design, and will improve on the management of the existing wildlife-crossing structures and underpasses, especially for threatened megafauna.

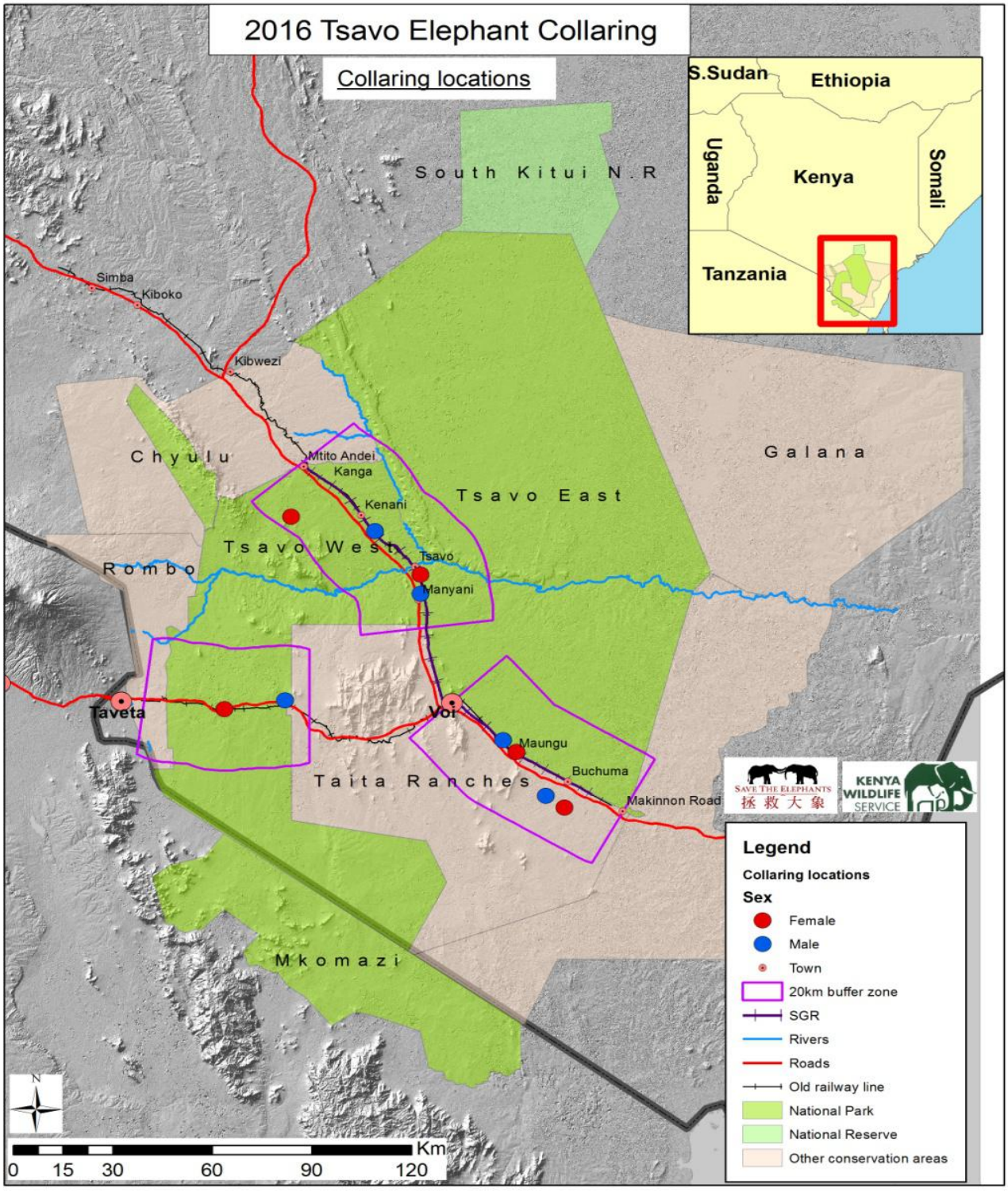


Figure 1: The collaring locations of the 10 elephants in the Tsavo ecosystem undertaken between 15th - 17th March 2016.

The collared elephants versus the SGR

Six out of the ten collared elephants crossed the SGR and the highways within the first four weeks of collaring them. Multiple crossings were later recorded within the first six months (Table 1).

Table 1: Individual elephant ranges calculated using Minimum Convex Polygon (MCP) estimation and the frequency of crossings of the SGR/Highway by the collared animals

Elephant ID name	Range area (km^2) based on MCP	Frequency of SGR crossings	Frequency of highway crossings
Taita	4,921	9	9
Kenani	2,923	104	45
Makitau	1,342	0	8
Murka	1,104	0	150
Rukinga	1,091	34	32
Ndara	958	0	0
Kamboyo	798	0	0
Maungu	459	0	0
Manyani	149	4	6
Tsavo Bull	75	4	129

One female named "*Kamboyo*" and her family have not crossed the SGR between Kenani and Mtito Andei most likely due to the busy construction activities taking place in the area. One female and one male, collared in south of Voi town, *Maungu* and *Ndara,* never attempted to cross the SGR. Two males, *Tsavo Bull* and *Manyani* crossed the Mombasa-Nairobi highway 129 and 6 times respectively but each crossed the SGR four times only. These two animals most likely used the Manyani Gate underpass to cross the SGR. However, the reduced frequency of SGR crossing compared to highway crossing by these animals was an indication of human disturbances at or around the underpass.

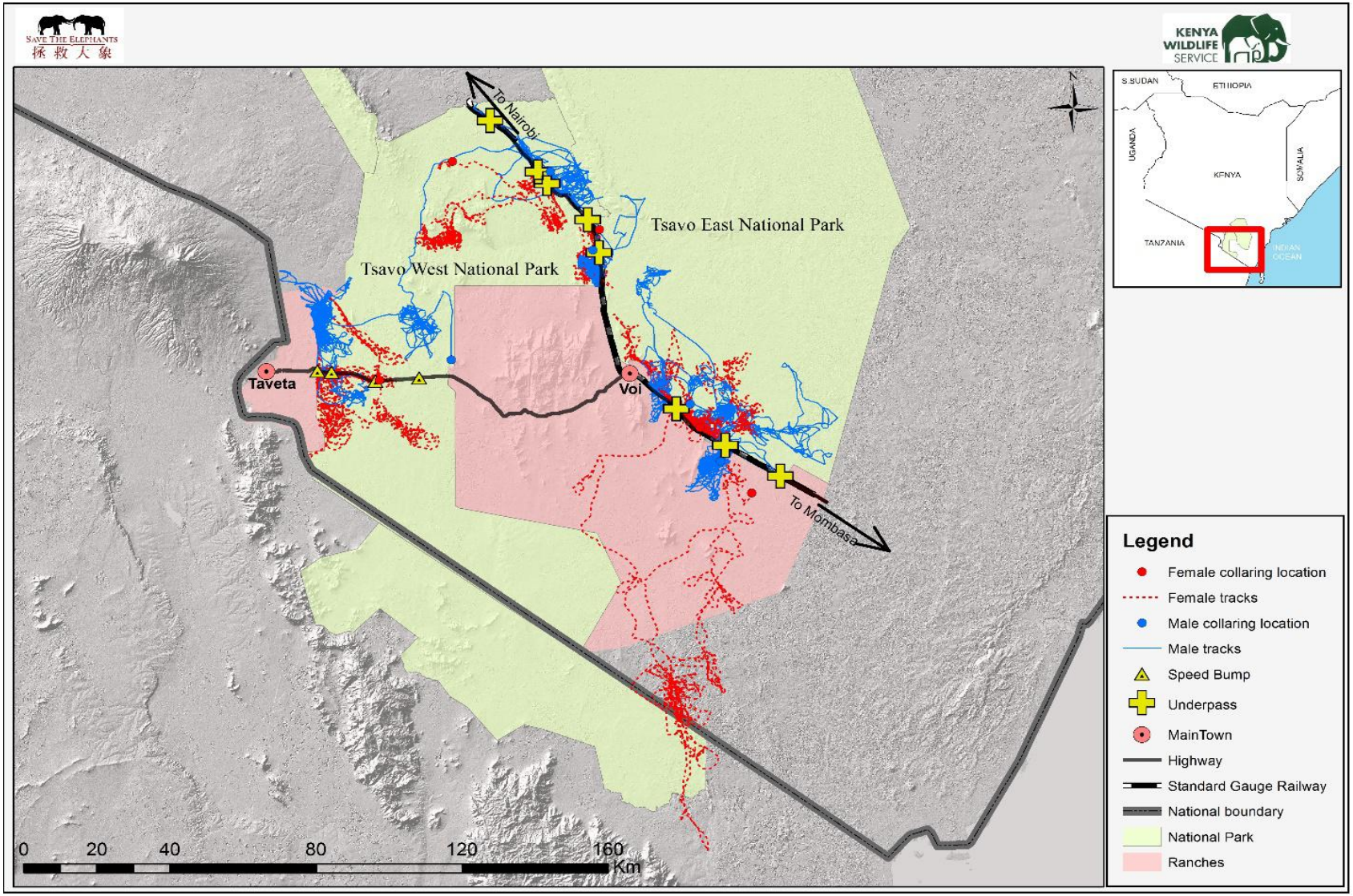


Figure 2: Movement tracks of 10 collared elephants in Tsavo ecosystem along the Standard Gauge Railway, the Mombasa - Nairobi and Voi - Taveta highways in March - September 2016.

Exceptional elephant movements

We also singled out the exceptional elephant movements of three individuals namely *Taita, Kenani* and *Rukinga*. Their movements were unique in range and frequency of crossing the SGR and highways (Table 1) and in distance and pattern (Figures 3a to 3c).

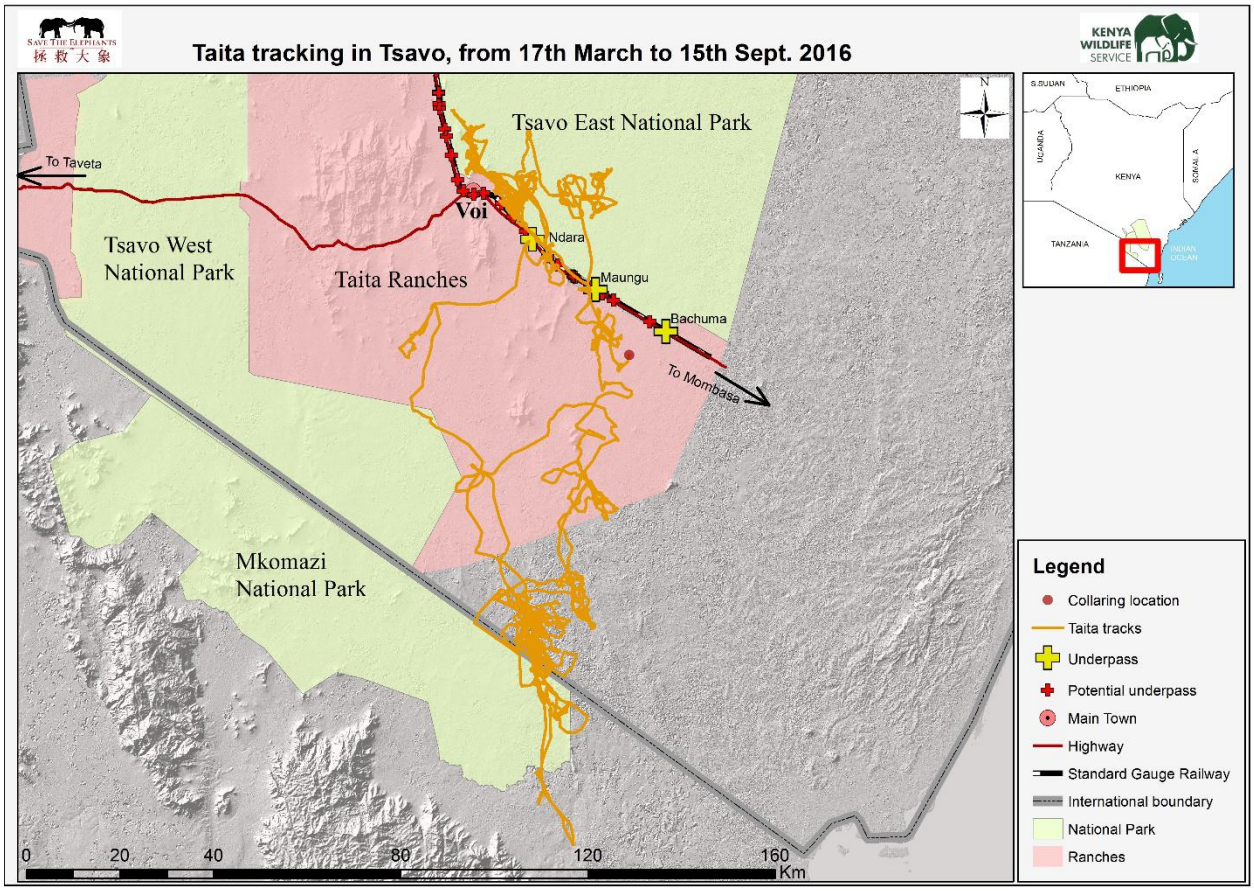


Figure 3a: The female elephant, *Taita's* movement from March to September 2016

The female elephant named *Taita* had the largest range of 4,920 km^2 (Table 1), stretching from north of Voi town in Tsavo East NP through the Taita Ranches and into and beyond the Mkomazi National Park in Tanzania. She was collared in Taita Ranch but was able to cross the SGR nine times through Ndara and Maungu underpasses (Figure 3a).

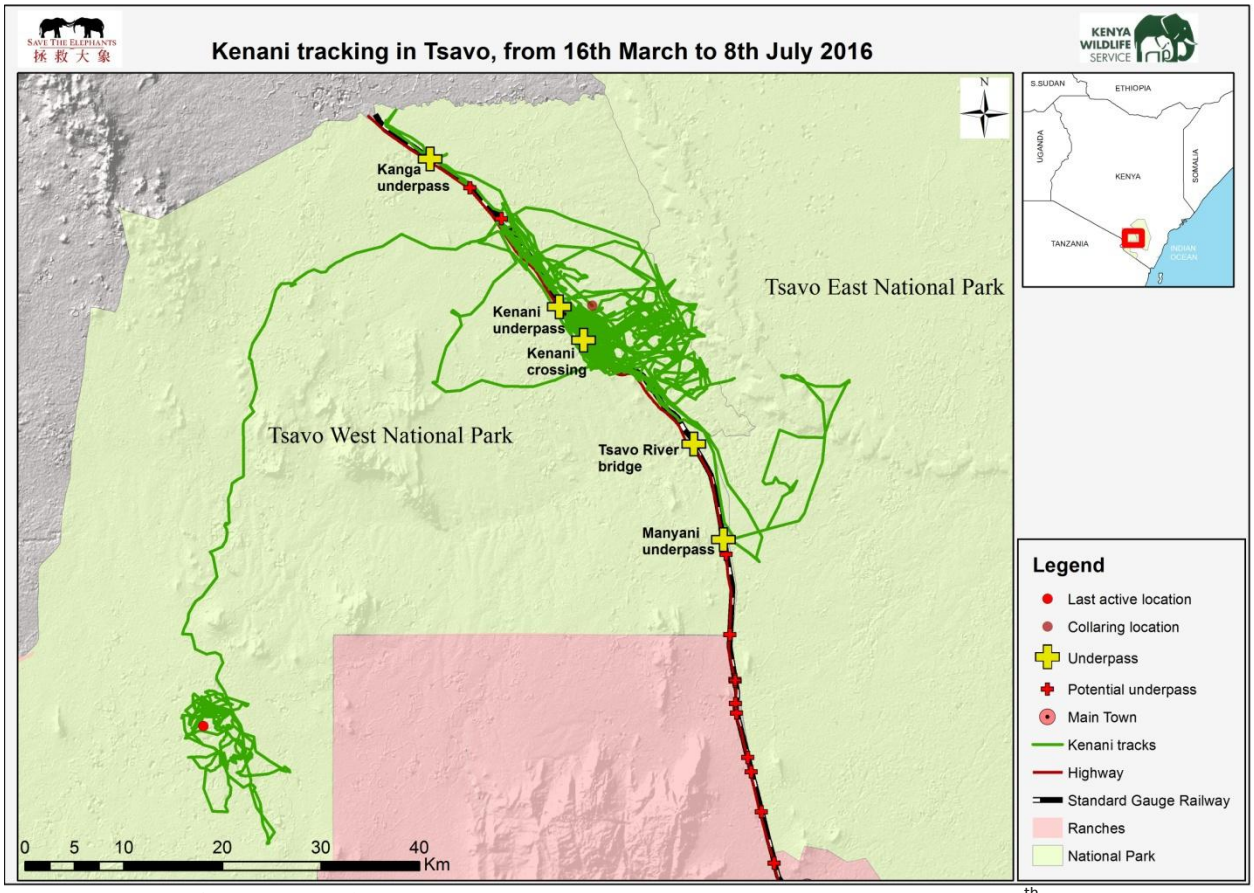


Figure 3b: *Kenani's* movement from March 16th when the bull elephant was collared until 8th July 2016 when he was found killed by poachers in north west of Makitau. Its poaching location is shown as the last active location on the map.

The bull *Kenani* was collared at Kenani area on the east of the SGR and Mombasa Highway. He spent almost 3 months moving along the SGR and Mombasa-Nairobi highway and crossing over to either side. This suggests that this individual bull was trying to learn how to cope with its newly fragmented habitat and blocked migration routes. *Kenani* crossed the SGR 104 times before moving approximately 73 km southwards into the heart of Tsavo West N.P in four days. Unfortunately, *Kenani* was later killed by poachers on 8th July 2016 in Tsavo West, north of Makitau area. The animal's satellite-linked collar sent a correct immobility alert to both STE and KWS staff which led to quick discovery of its carcass.

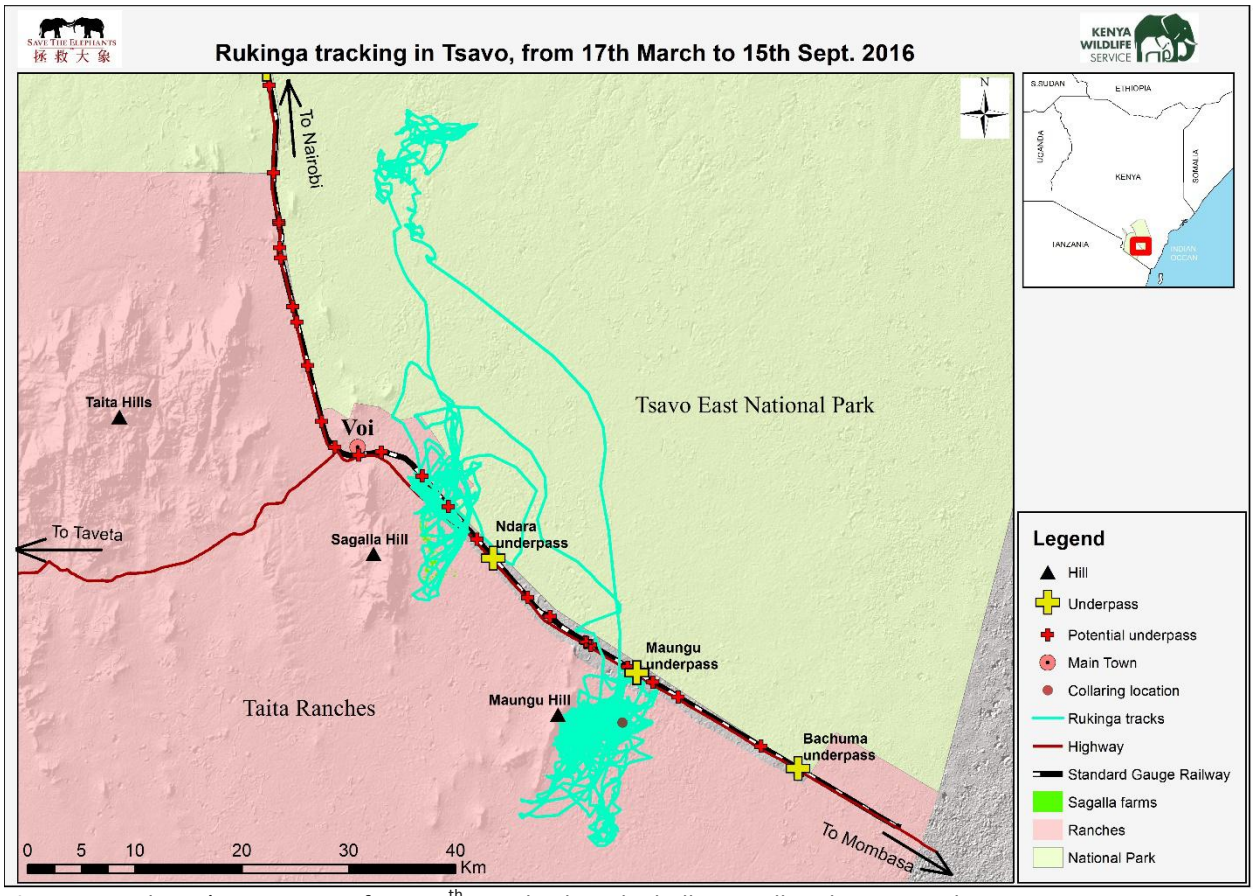


Figure 3c: *Rukinga's* movements from 16th March when the bull was collared to September 2016

Rukinga had a range of 1,091 km^2 extending from Mbololo north of Voi town to the Sagalla foothills where he displayed frequent crop-raiding behaviour before he moved on south to the ranch of Rukinga Wildlife Sanctuary south of Maungu town as shown in Figure 3c. This individual crossed the SGR 34 times and most of the crossings were to and from Sagalla farms and Ngutuni Wildlife Conservancy. *Rukinga* crossed the SGR mostly at Ngutuni area and some of the crossings are evidently through the culverts in Ngutuni area i.e., Ngutuni Conservancy entrance culvert.

Elephant movements and density maps

Here we show elephant movements by sections along the SGR and highways. High to low use areas are shown using Kernel density method in the sub-set figures. Figures 4a & 4b and 4c & 4d show confined elephant movements along the SGR. This confinement may suggest that the elephant movements were restricted by the raised SGR and other infrastructure along the SGR. The bushes between the highway and the SGR across Ngutuni Wildlife Conservancy have been found to be a high usage area for elephants. Many elephants therefore cross the SGR to access this site and thus emphasizing the need to ensure that Tsavo East and Tsavo West National Parks are connected as one ecosystem. This assertion is also corroborated by the monitoring data collected for three months along the SGR (see section of monitoring of wildlife species crossing the SGR in this report). However, figures 4e & 4f show a well spread elephant movement and distribution in the western section which implies the Voi - Taveta road is not a significant barrier to elephant movements.

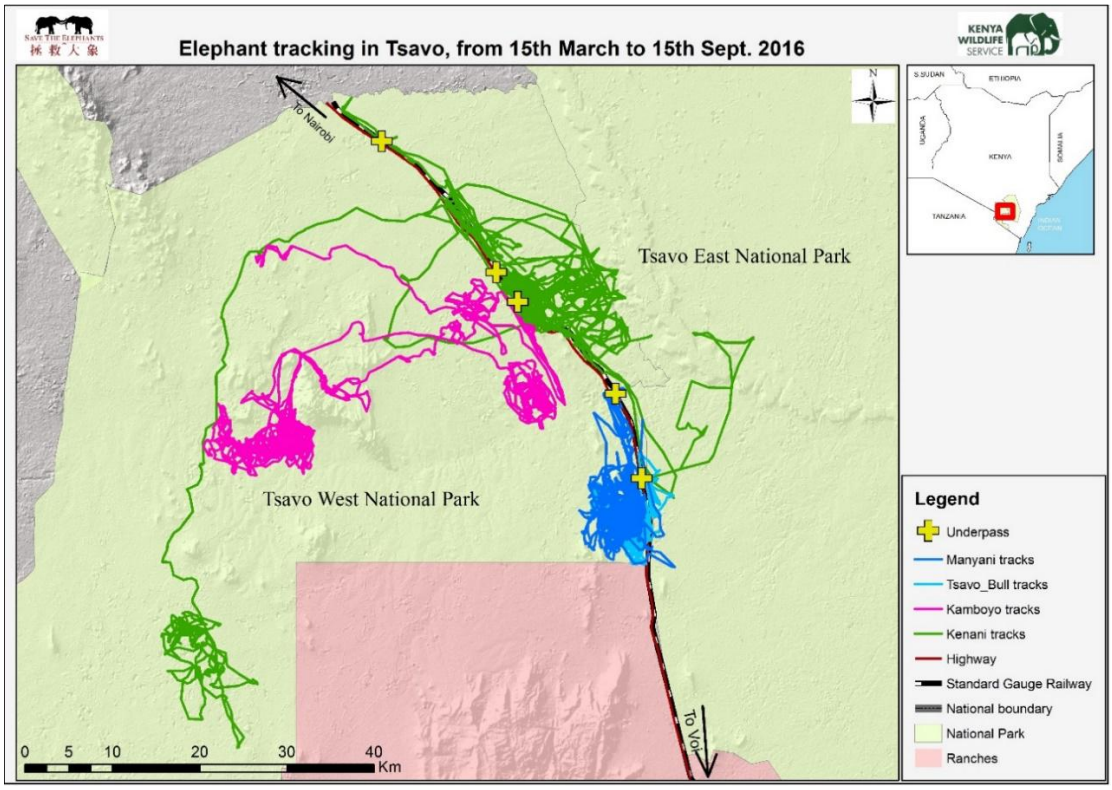


Fig. 4a

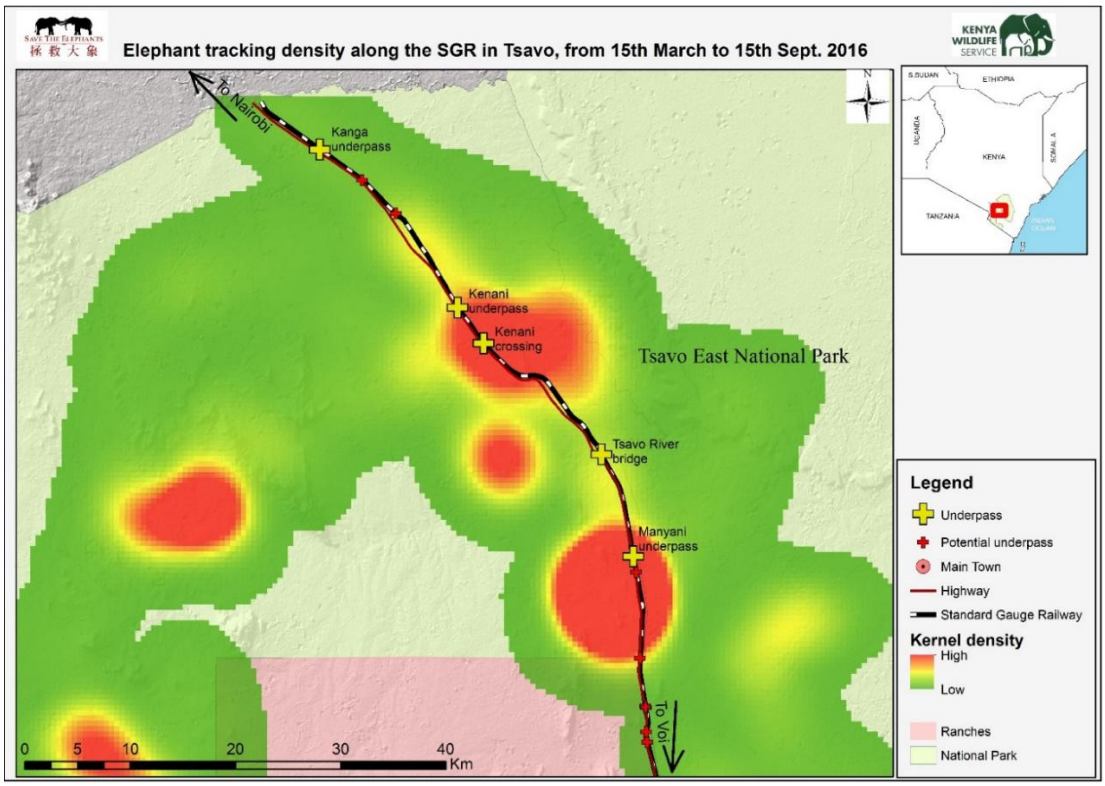


Fig. 4b

Figures 4a & 4b: Elephant movements and density map in Voi - Mtito Andei the northern section of the study area. The locations of the main underpasses and other potential underpasses along the SGR are also shown

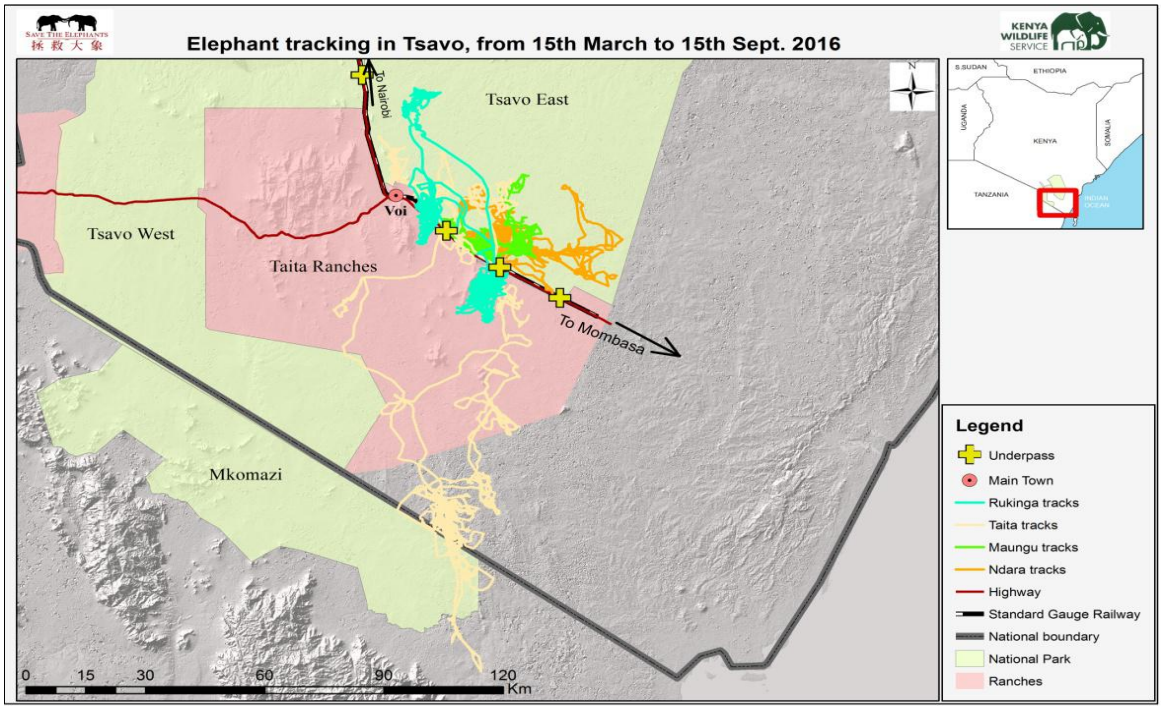


Fig. 4c

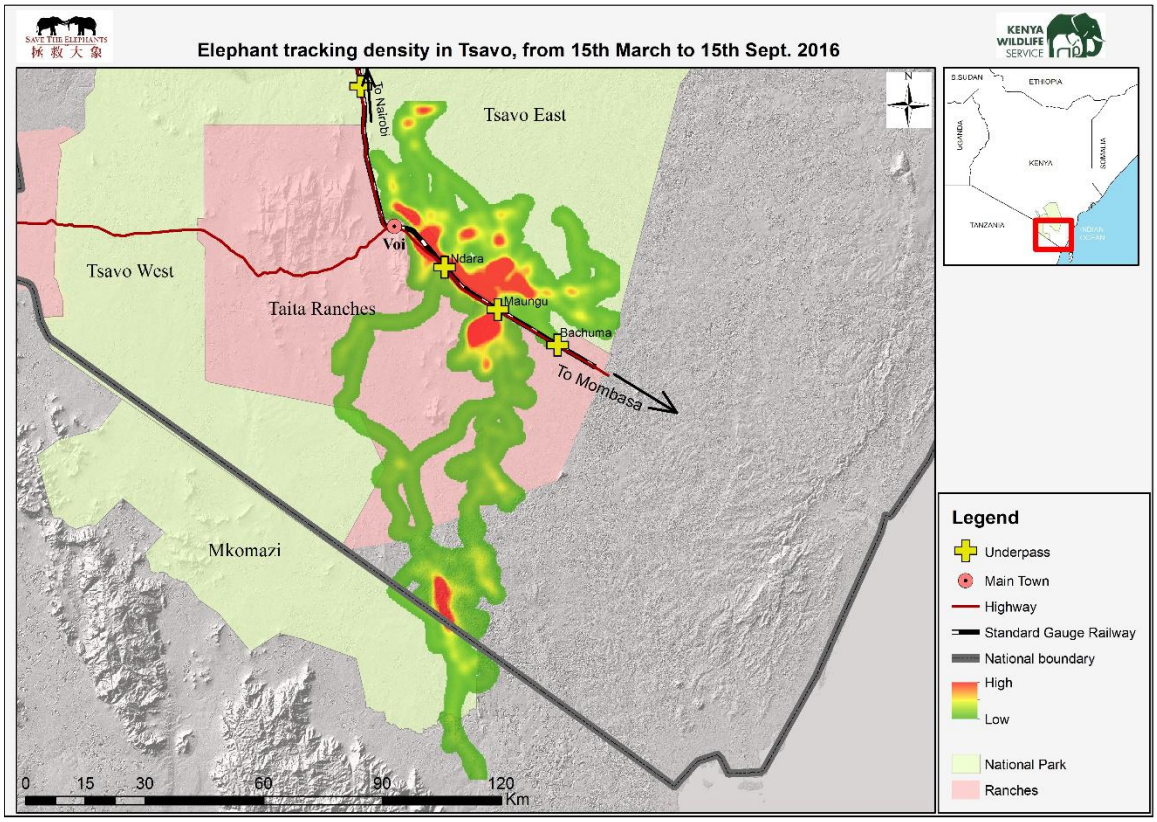


Fig. 4d

Figures 4c & 4d: Elephant movements and density map in Voi - Bachuma the southern section of the study area. The locations of the main underpasses in this section and other potential underpasses are also shown.

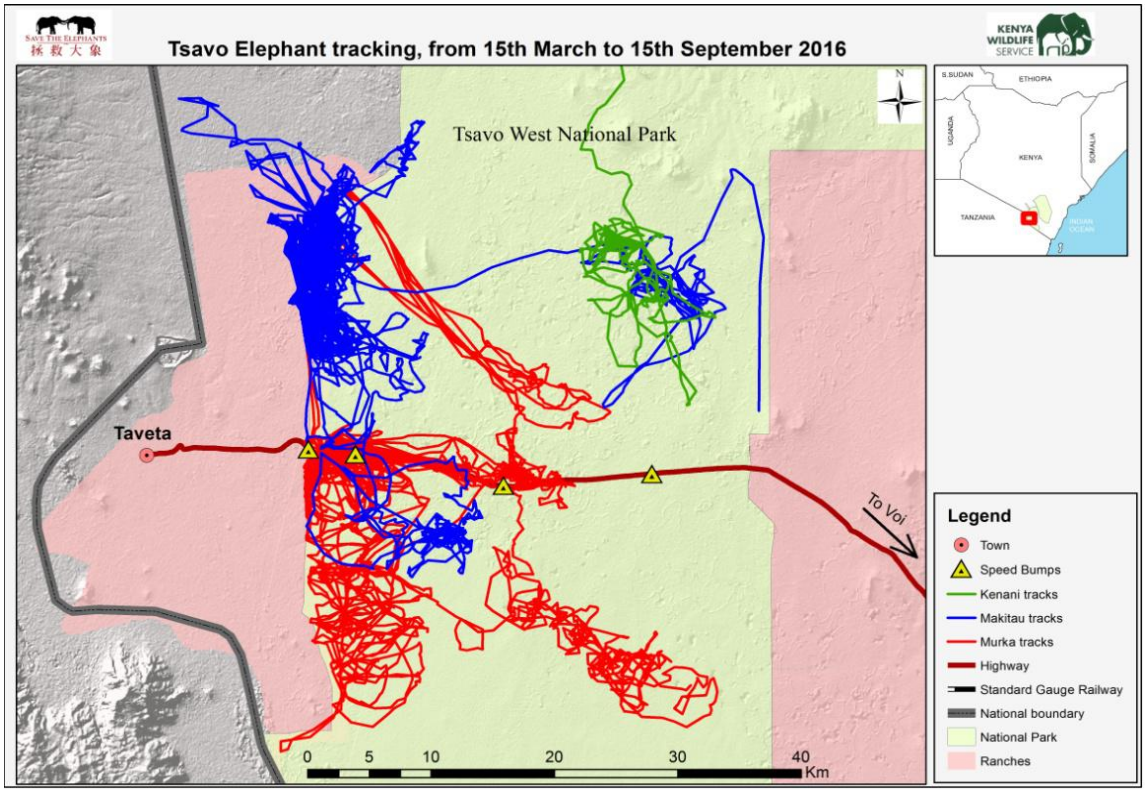


Fig. 4e

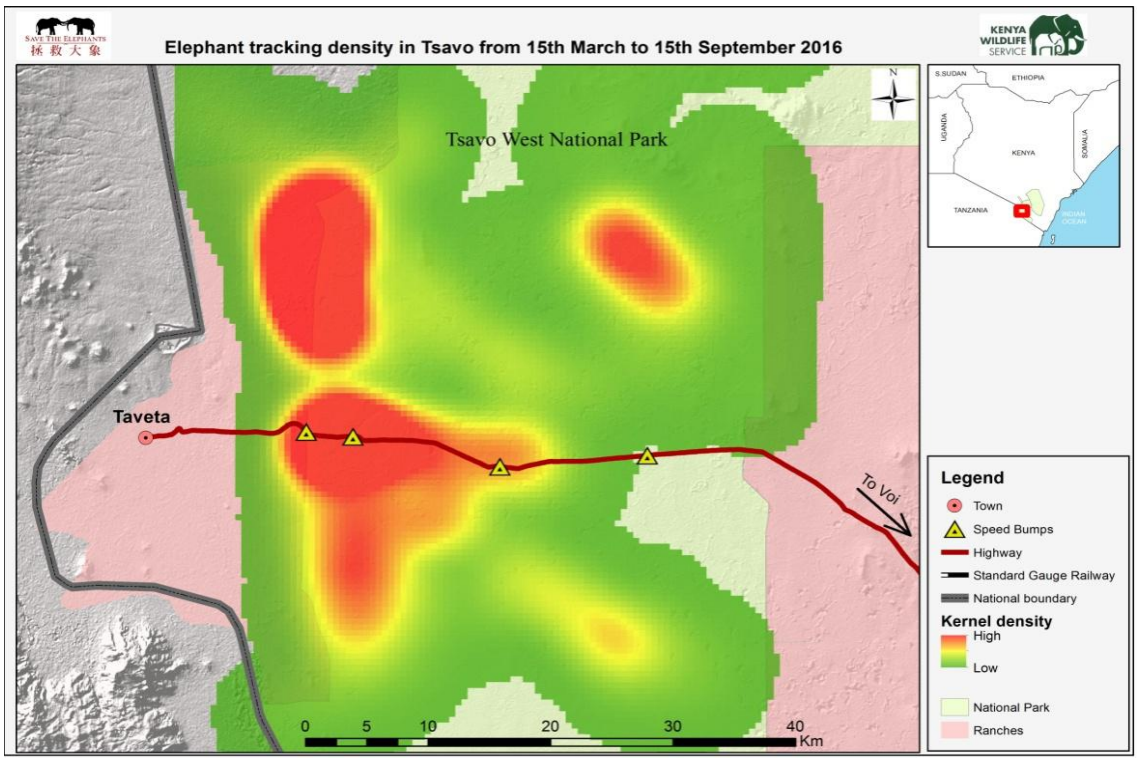


Fig. 4f

Figure 4e & 4f: Elephant movements and density map in Voi - Taveta, the western section of the study area. The locations of speed bumps along the Voi - Taveta highway are also shown

Elephant movements in relation to other infrastructure development

Figures 5a and 5b show restricted elephant movement mainly due to the heavy infrastructure development around Manyani and Ngutuni shopping centers. Despite the presence of underpasses in those areas, their longer-term use by elephants and other wildlife species is compromised by these new developments. South of Voi town, the thick bush land between the highway and the SGR that crosses Ngutuni Wildlife Conservancy are high use areas for elephants before setting out for crop-raid events (figure 5b). The elephants have been crossing the SGR to access this site. This has been corroborated by the monitoring data collected for three months along the SGR. Sustainability of the underpasses along the SGR can only be guaranteed if they are left clear and devoid of human settlements and developments around them.

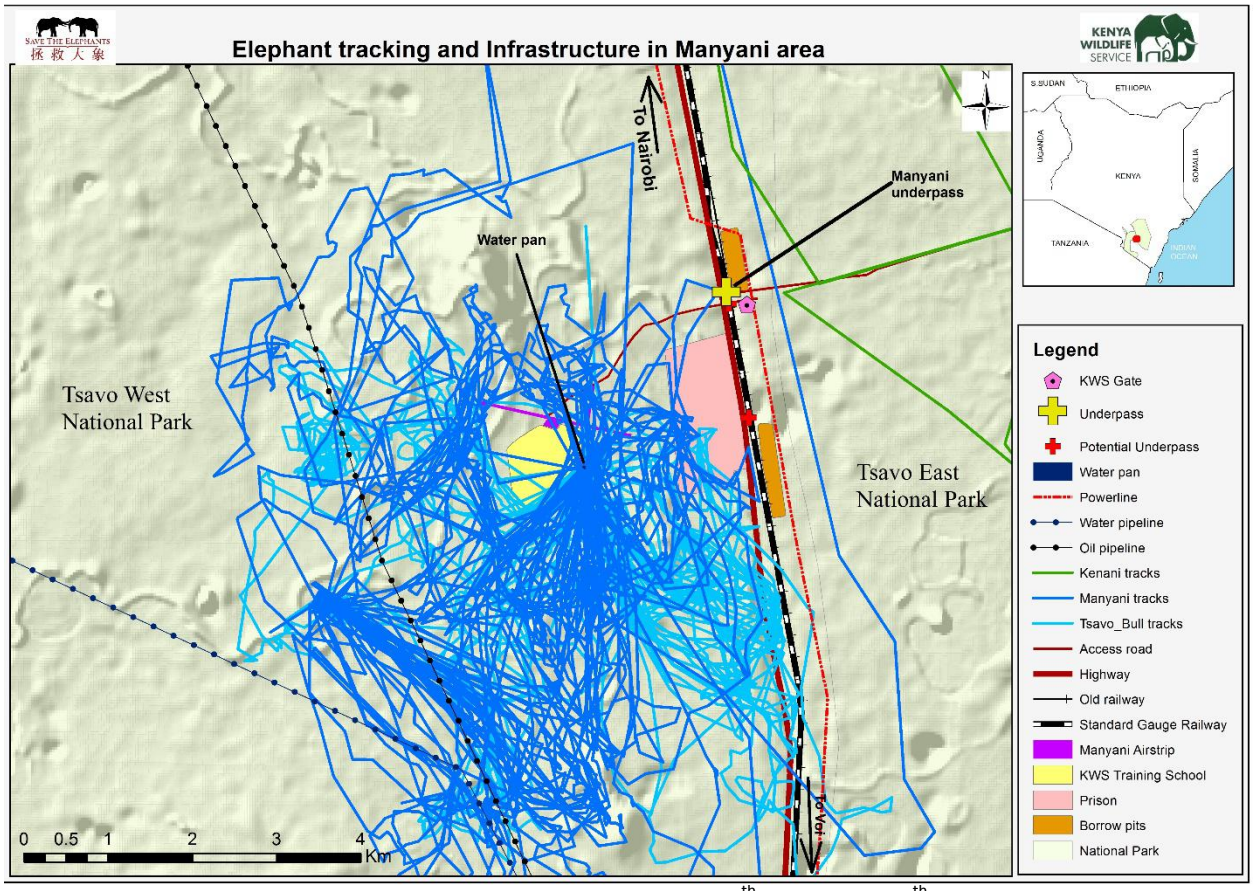


Figure 5a: Map showing movements of three elephants between 15th March and 15th September 2016. It is evident from the map that the developments around Manyani are restricting elephant movements.

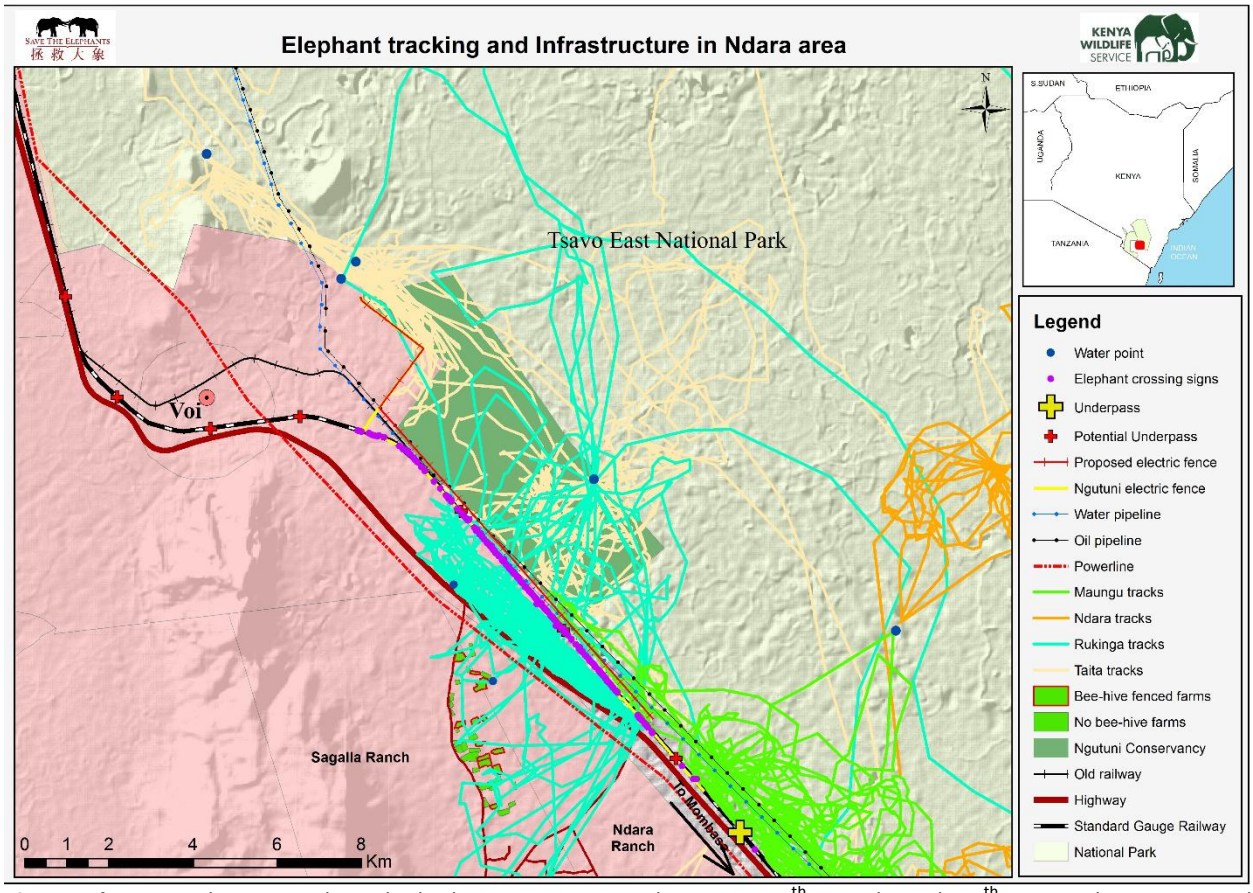


Figure 5b: Map showing selected elephant movements between 15th March and 15th September 2016 and infrastructural barriers blocking elephants between the highway and the SGR in the Ngutuni Conservancy area. The Ndara underpass appears not to have been used by any tracked elephants.

Effects of water sources on elephant movements

It is clear from the six months of tracking data that the elephant movement around the SGR are restricted by the raised SGR and the construction activities taking place along the Bachuma - Mtito Andei. Figure 6 also shows that elephant movement is influenced by sources of water. This is even more reason for ensuring that all the underpasses and the wildlife-crossing structures along the SGR are maintained and sustained. That way, a continued access to vital resources such as water and food on either side of the SGR are ensured. As a compensation for restricted movement to water resources, there may be a need to consider providing water to elephants at places where they find difficulty accessing water because of the SGR's barrier of raised embankment. This should however be done in consideration of the fact that such water provisions tend to exacerbate habitat degradation due to high wildlife concentrations around them.

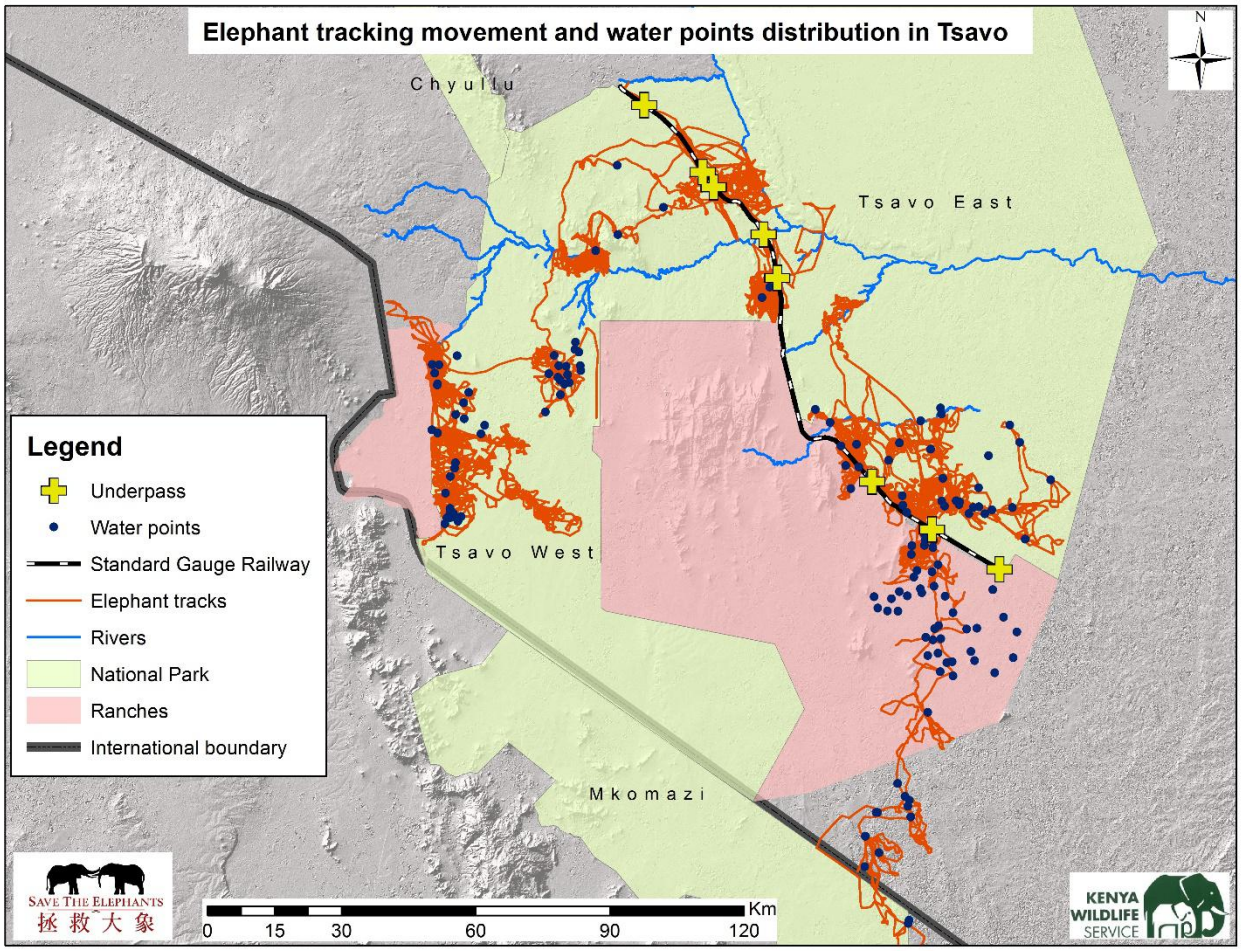


Figure 6: Map showing movements of collared elephants between 15th March and 15th September 2016 and their overlap with the water points distribution

Other wildlife species versus the SGR

Three times per week beginning 24th June 2016, one team from Wildlife Works and one team from KWS Voi HQ monitor the Voi - Bachuma (DK 140 to DK 90+360, approximately 50 km) and the Voi - Mtito Andei (DK 144 to DK 239, approximately 95 km) sections respectively. This is done by driving an open vehicle with two observers or by riding on motorbikes slowly along the SGR service road for signs of animals that crossed the SGR. Double counting of the signs was minimized by marking the already recorded animal crossings using sawdust. As of October 2016, a total of 1,036 incidences were recorded of wildlife crossing the SGR by climbing over it or by walking through the designated underpasses and culverts. Seven hundred and sixty eight (768) crossings were made by elephants. These comprised 74% of the total incidences of animal crossings. This suggests that elephants are the species most affected by the SGR, or could be an indication that elephants are not bothered by it as they crossed, but other wildlife species were prevented from trying to cross. The individual points of wildlife crossings during

this monitoring period are shown in Figure 7. The game-proof SGR fence will prevent these movements over the SGR where there is no underpass and therefore culverts should be unfenced to allow movement.

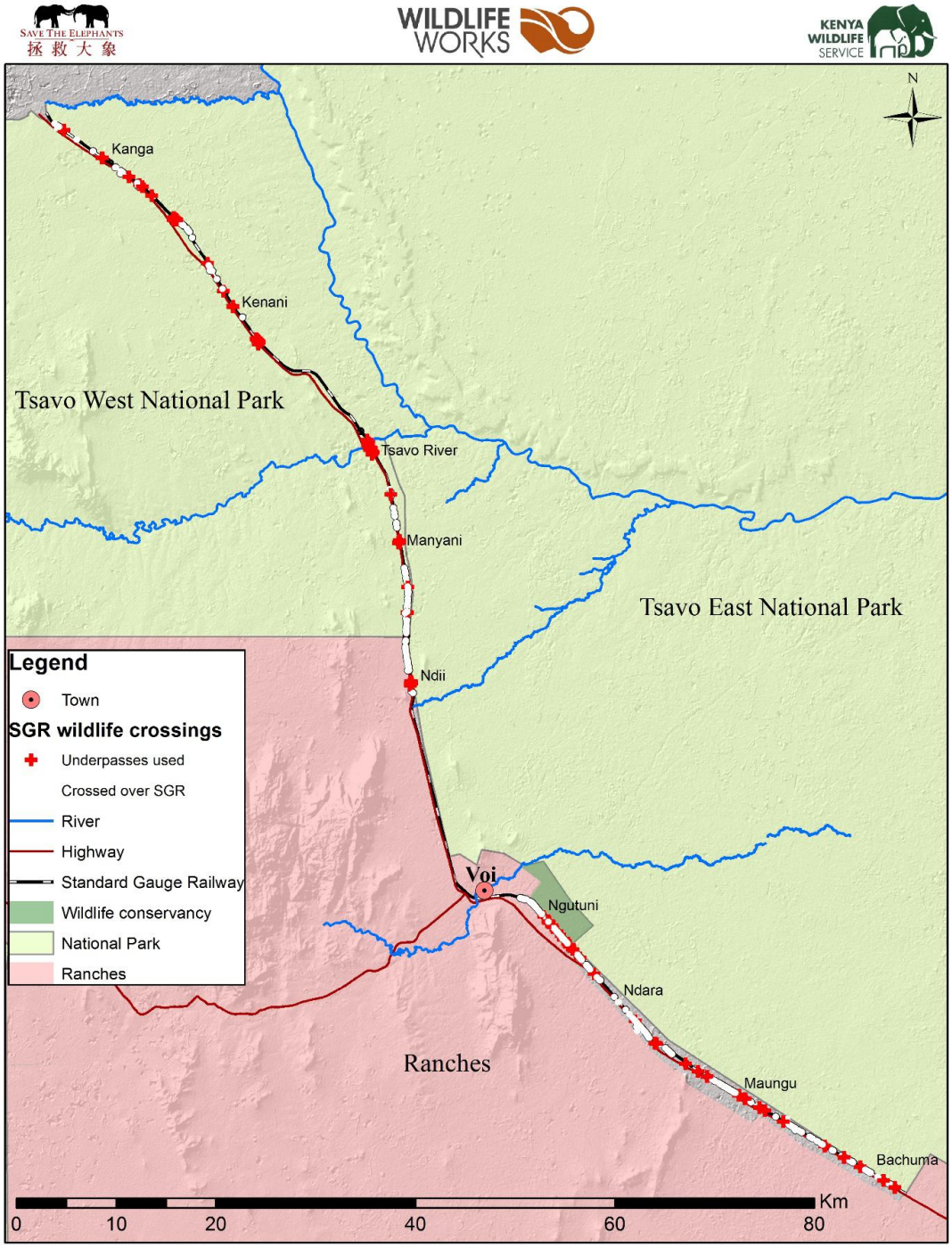


Figure 7: An overall map showing wildlife crossing points along the SGR from Bachuma to Mtito Andei. The red cross signs are areas where wildlife crossed the SGR using a designated underpass, a bridge or a culvert. The white dots are areas where wildlife species were recorded as having climbed over the SGR embankment.

Voi - Bachuma section wildlife crossing the SGR

The Ngutuni Conservancy area in the approximately 50 km Voi - Bachuma SGR section had more wildlife crossing activities than other areas (Figure 8a). It had 391 (62%) of the total 631 wildlife crossing activities recorded between Voi and Bachuma. The frequently used underpasses in Ngutuni area included the vehicle underpass at DK131+969 and culverts at DK131+397, DK132+790, DK134+984 and DK135+112. These numbering are indicated by the SGR contractors to indicate Distance in Kilometers (DK) from Mombasa. The suffix numbers after the plus (+) represents meters. All the mentioned culverts, except one, have a width of between 4 and 6 meters and a height of between 3.2 and 4 meters. Interestingly, the elephants have frequently utilized culvert DK131+397 which has a width of 3 meters and height of 3.5 meters at Ngutuni. Underpass DK131+969 recorded the most utilization incidences of 17 crossings by elephants. Animals had climbed the SGR embankments and crossed over while others had utilized the culverts (Plates 2 & 3). It is important to note that all of these wildlife underpasses crossing points between Voi and the Ndara Underpass have since been closed off to elephants and other wildlife species by the construction of a 14 - strand electric fence which was completed by the David Sheldrick Wildlife Trust and KWS at the end of September 2016.

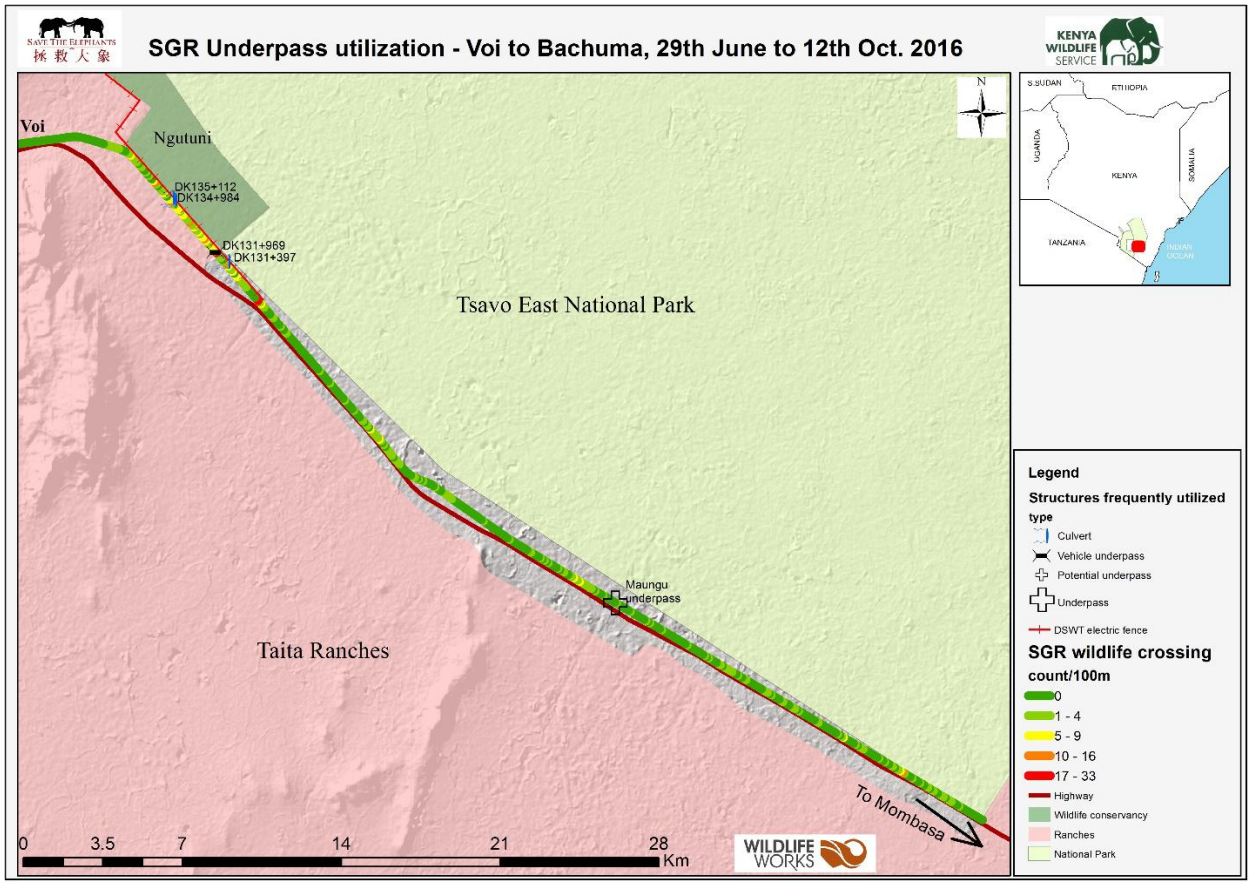


Figure 8a: Map showing areas which were utilized by wildlife when connecting from one habitat to another along the SGR from Bachuma to Ngutuni. The orange/red points were the most frequently used crossing points, both through underpass and over the SGR, while the green areas were the least utilized crossing point areas.

The Maungu rail crossing and the Maungu underpass were the most utilized with more than four crosses within the 6 months monitoring period. Ndara area had 289 incidences where elephants climbed the SGR embankment and crossing over the SGR. This was close to half of all the 598 cross-overs made along the entire 135 km SGR section inside the National Parks (See Plate 3 for evidence of cross-over). However, of significance to note was the lack of utilization of Ndara underpass, the only purposed elephant underpass that has been constructed between Voi and Maungu (See Figure 8b). This is a strong indication that heavy development around the Ndara underpass could still be impeding the use of that underpass by elephants. The Tsavo management and the transport industry should also be aware that this area requires more faunal passages and extra safety measures for the trains and vehicles.

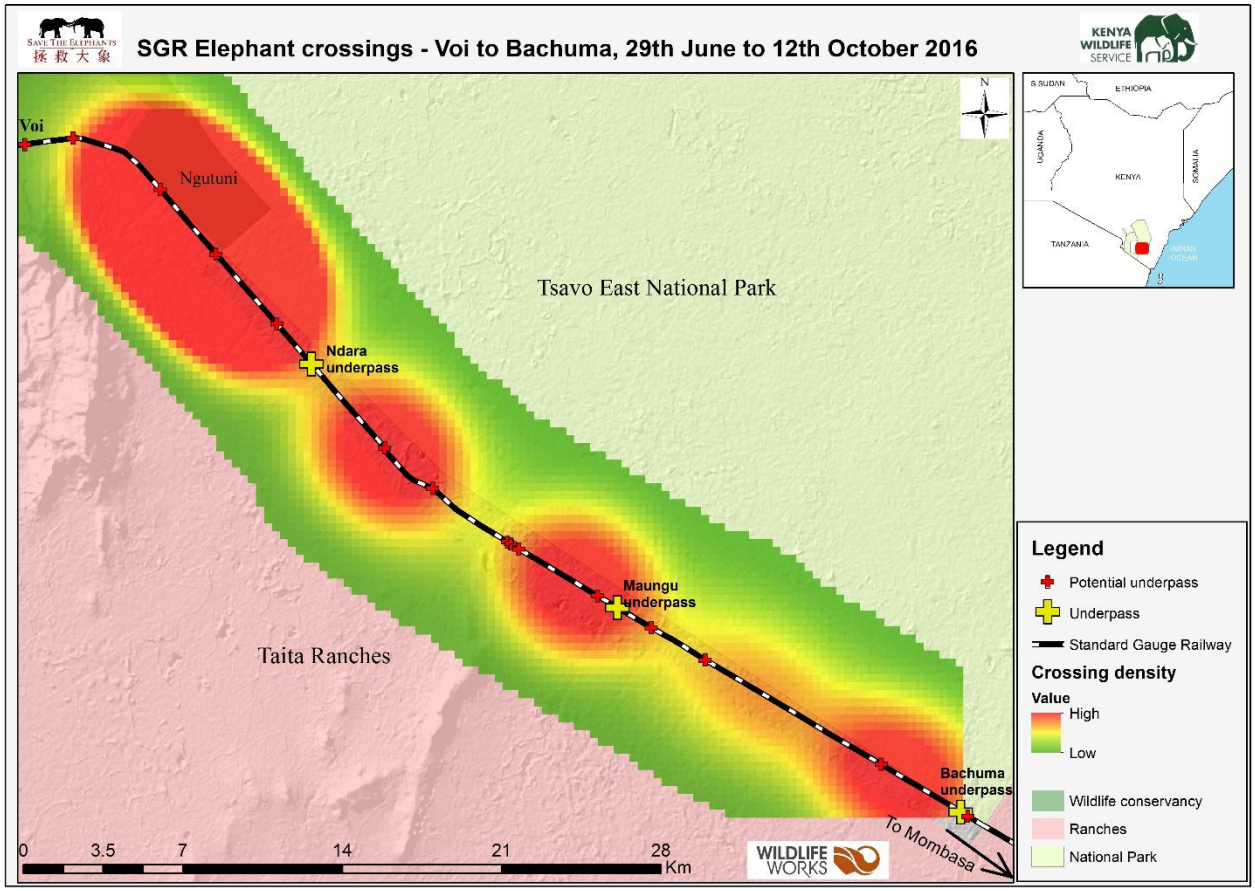
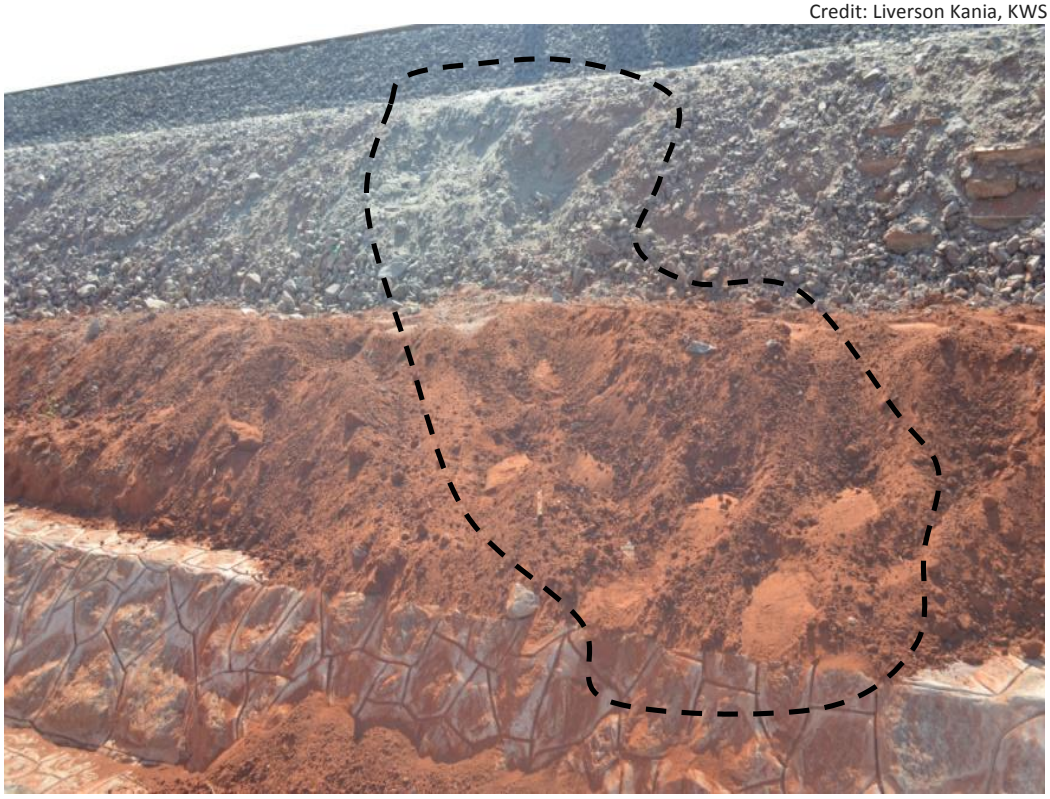


Figure 8b: Showing the animal crossing incidences between Voi and Bachuma. The Ndara underpass is presently the least utilized and likely to be due to the ongoing construction and human disturbance at this junction

Credit: Liverson Kania, KWS 2016



Credit: Dennis Kibara, KWS 2016

Plate 2: A photograph of elephants climbing over the SGR embankment (above) and below is a photograph of elephant footprints (circled by dotted lines) crossing the SGR at another location

Voi - Mtito Andei section wildlife crossing the SGR

The most frequently used underpasses and bridges were Ndii bridges, Manyani underpass, Tsavo River Bridge, Kenani old rail/SGR crossing point, Kanga underpass and culverts DK174+205, DK222+394, DK222+500 and DK227+198 in the approximately 95 Km Voi - Mtito Andei section. Ndii water bridge experienced the highest usage with 40 incidences. Manyani underpass was utilized 37 times and the Tsavo River Bridge underpass was used 31 times. Most notably elephants, buffaloes, zebras and carnivores were recorded as regular users of these faunal passages between Tsavo East and Tsavo West National Parks. There were a lot of incidences between the DK 170 to DK 180 culverts where elephants climbed and crossed over the SGR embankment. Culverts from DK 210 to DK 230 were heavily utilized by elephants as faunal passages/underpasses and they also climbed over the SGR in this area (Figure 9a & 9b).

It was evident that apart from the six underpasses purposely constructed for the wildlife crossings and dispersal, other potential faunal passages such as bridges for water flows, old railway/SGR crossing points and drainage culverts were utilized by wildlife for their dispersal (See Plate 3). There were many attempts by elephants to climb up the steep SGR embankments with 598 incidences of successful climbs over the SGR and slides down the other side.

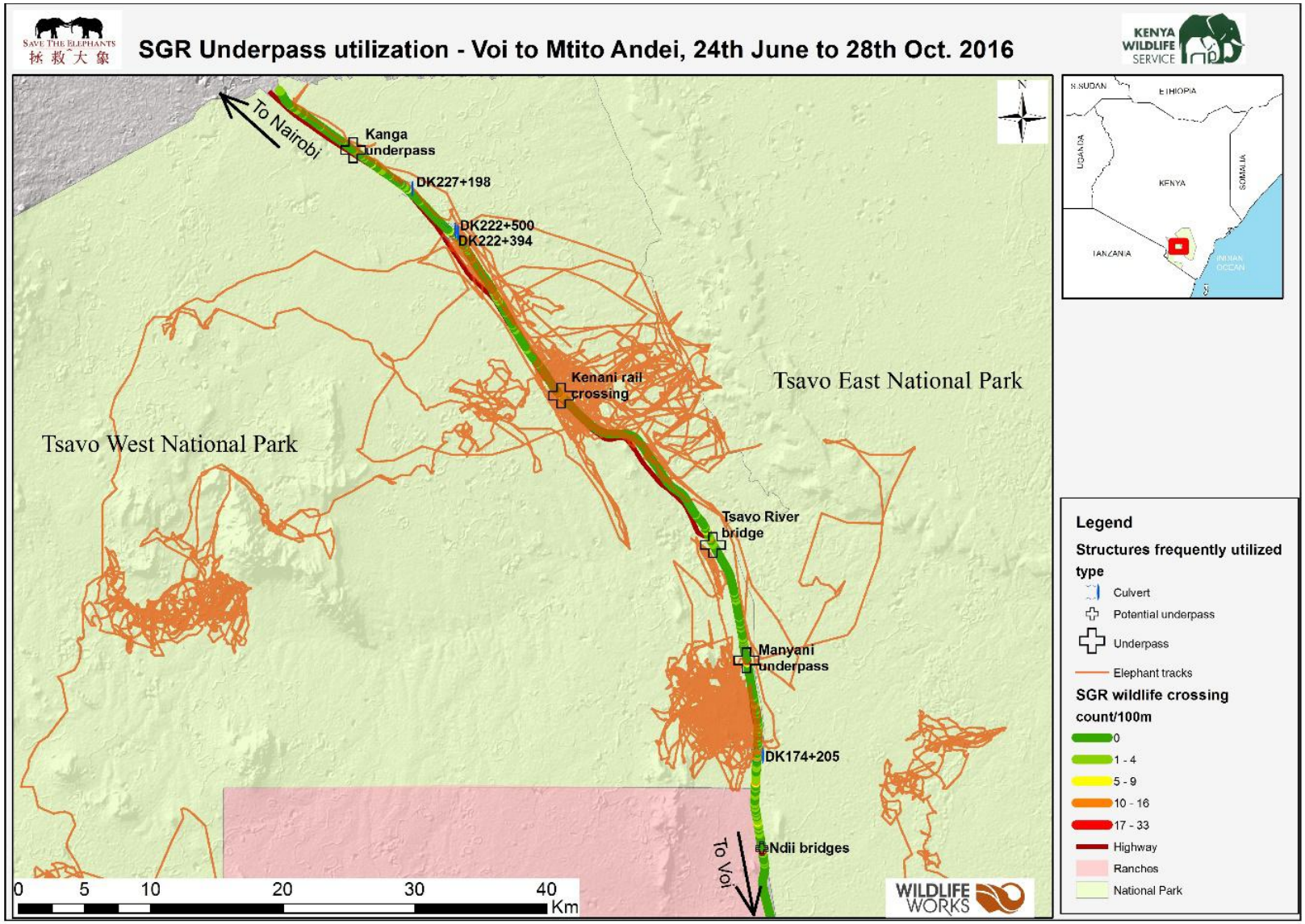


Figure 9a: Wildlife crossing points along the SGR between Voi and Mtito Andei in Tsavo East and Tsavo West National Parks showing a critical need for the two National Parks to be connected as one ecosystem.

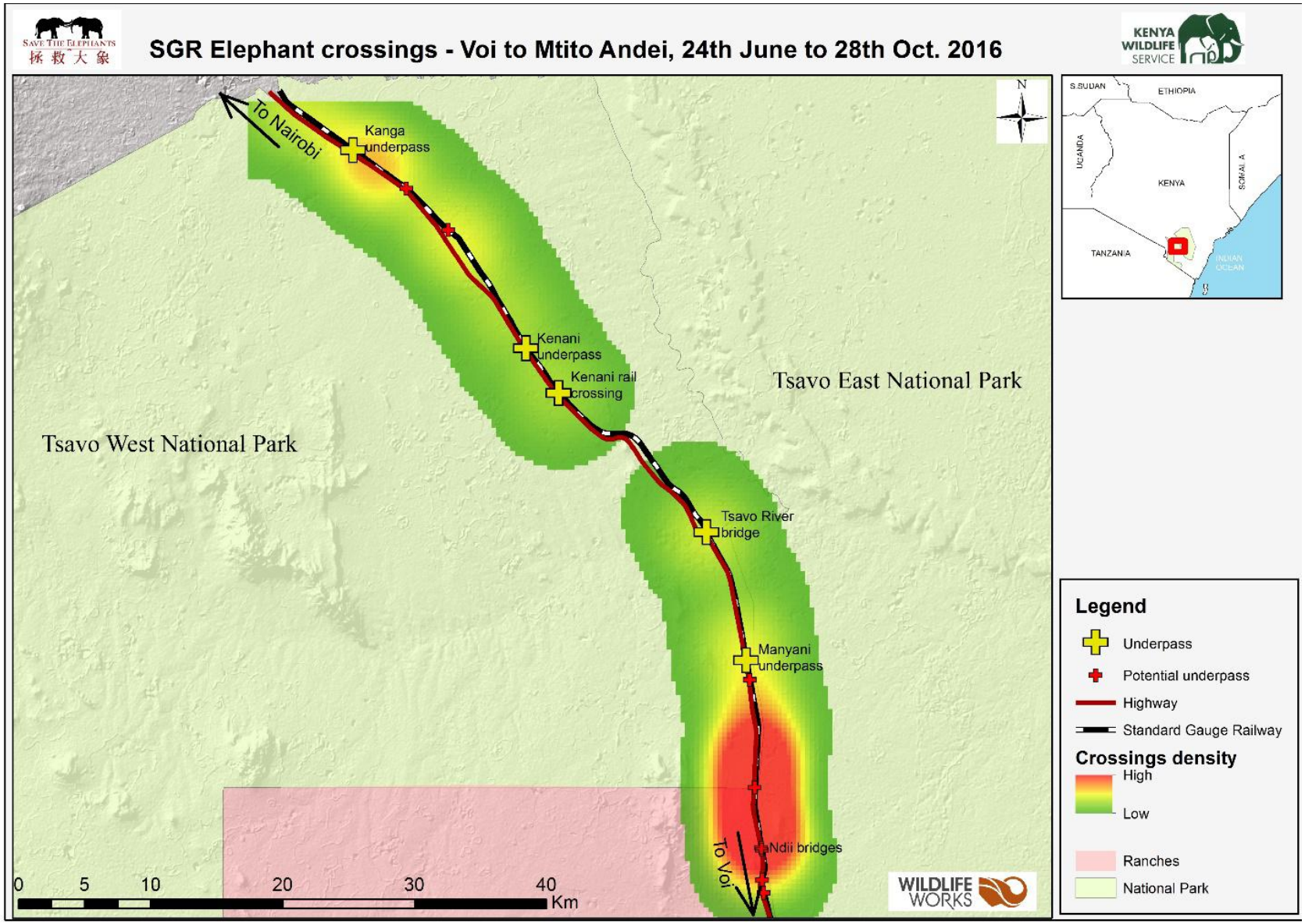


Figure 9b: Density map of frequency of incidences of elephant and other wildlife tracks crossing the SGR between Ndii and Mtito Andei

Credit: Alex Mwazo, KWS 2016

Plate 3: Elephant dung as evidence of utilization of drainage culverts along the SGR.

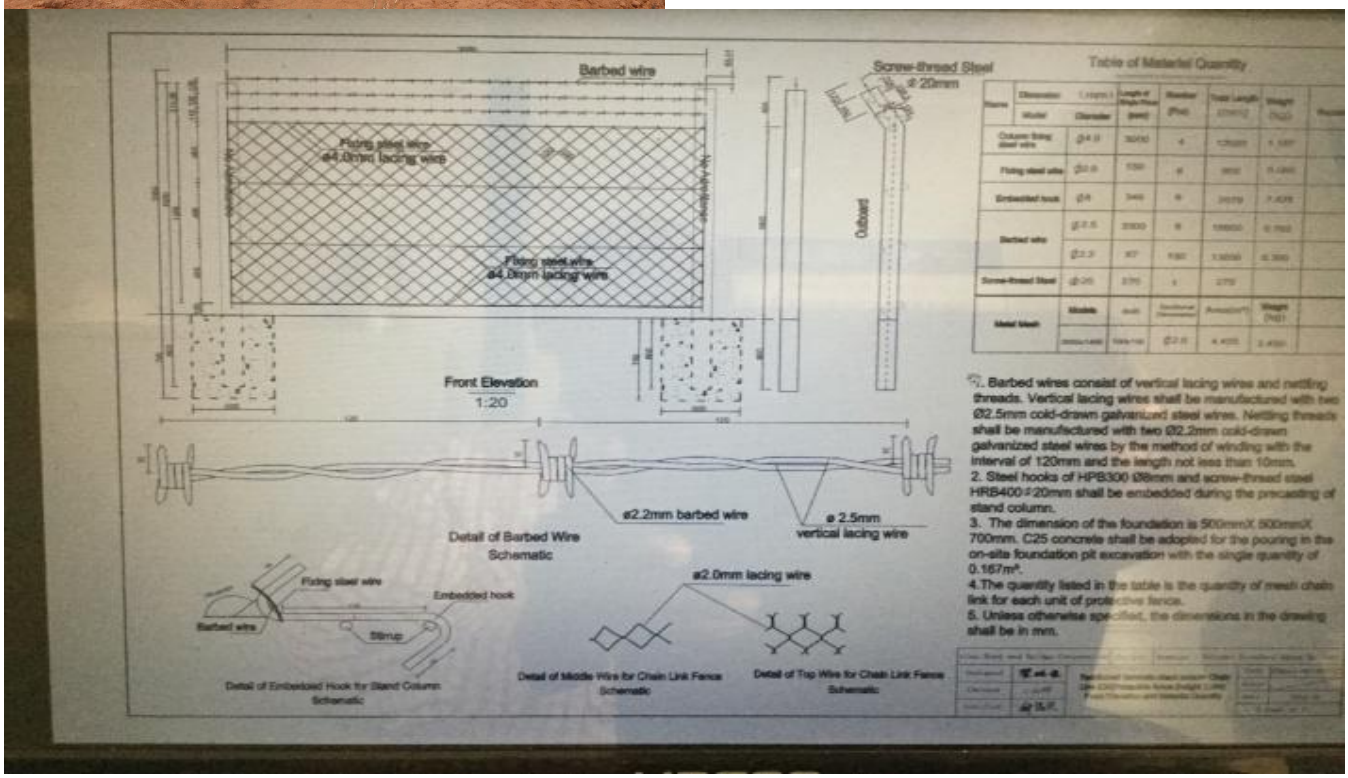
The SGR fence-line and wildlife movements

The 135 km section that bisects the Tsavo Ecosystem will imminently be fenced and closed on either side of the railway embankment to ensure passengers' safety by minimizing the likelihood of trains hitting animals climbing over the SGR. Elephants climbing over the SGR will inevitably occur (see Plate 2) unless an effective and well-maintained elephant-proof fence is erected parallel to the SGR. The type and design of the fence is therefore of utmost importance. Unfortunately, the fence that was being constructed during the period of this study to keep wildlife from approaching the railway tracks was in no way elephant-proof, because it lacked power and use of chain-link that is prohibited in a game proof fence. It had been trampled down by passing elephants within one month of construction of some sections (See Plate 4). If an SGR train hits an elephant at 120 km/hr the consequences would be dire for passengers, train and elephant. More so, vandalization of a chain-link fence is more likely than of electric fence and could potentially be used as wire snares for smaller wildlife species. The only way of avoiding a potential catastrophe, we believe, is to construct a full electrified elephant-proof fence and as

such, KWS stopped the contractor from continuing with the construction of the chain-link fence in August 2016. Effective designs such as that one shown in Plate 5a that was proposed by KWS and submitted to the SGR contractors are already available and up and running in many parts of Kenya. We are pleased to report here that construction of a 200 m trial electric elephant-proof fence around Manyani area began in October 2016, and awaits approval from KWS (Plate 5b).

Credit: Tsavo East, KWS 2016

Plate 4: The SGR fence as constructed by the SGR contractors between March and September 2016 to prevent wildlife from crossing over the SGR embankment. Sections where elephants have trampled down the fence are shown. The structural design of this fence, courtesy of the SGR contractors, is also shown below.



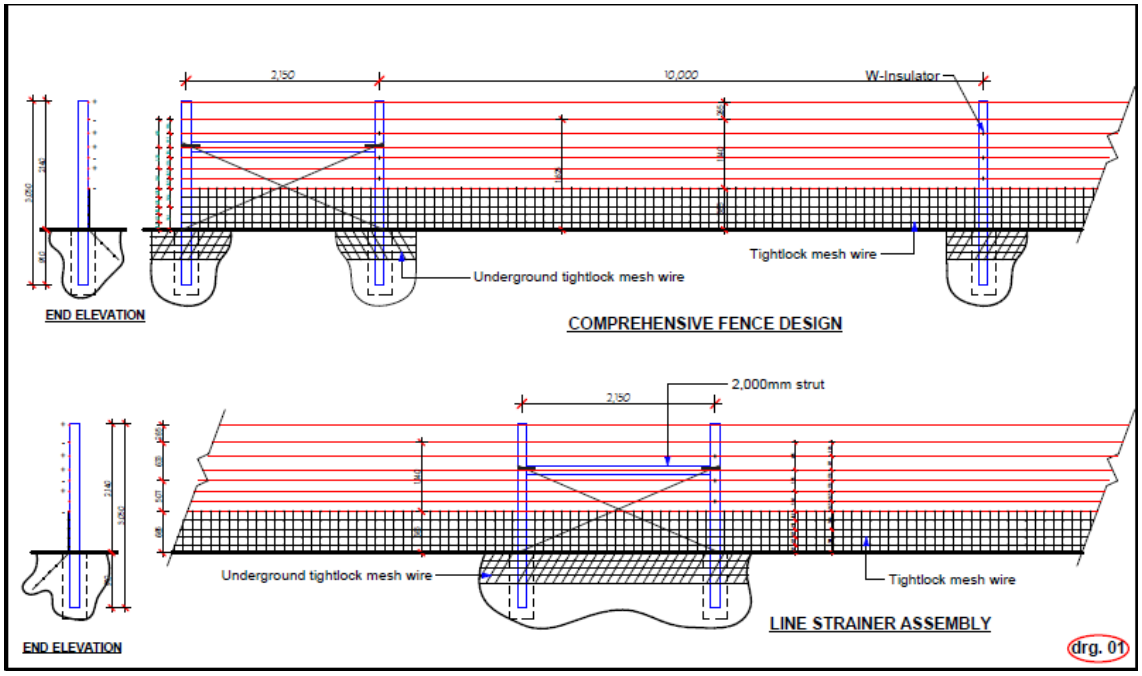


Plate 5a

Plate 5b

Plate 5: a) Elephant-proof electric fence as designed by KWS and submitted to the SGR constructors, and **b)** a 200 m section of trial elephant-proof fence under construction around Manyani shopping center as at November 2016.

Management Recommendations

1. From the movement patterns of the collared elephants, we observed elephants moving in a linear manner following the SGR. It is likely these elephants were searching for the new underpasses which was evident from dung deposited around the entrances to underpasses and culverts. The SGR electric fence should be designed to direct/funnel the animals climbing the embankments into the appropriate underpasses, or into specific open culverts along the most densely used sections of the railway. Most crossings were in Ngutuni, Ndara and from DK 167 to DK 180 in the Ndii areas. Wide culverts in this section should ideally not be blocked or fenced off but be left open to increase the number of faunal passages and to improve on the ecosystem connectivity.
2. The Kenya Highway National Authority must consider constructing wildlife over-passes or vehicle tunnels for the Mombasa highway sections that are adjacent to the SGR underpasses to ensure that elephants can safely cross both the SGR and the newly expanded highway. This is to ensure a reduction in human fatalities at these concentrated wildlife points as much as to reduce wildlife accidents on the road. In the short term, it will be important to erect a series of traffic speed bumps on the Mombasa - Nairobi highway adjacent to all unfenced culverts and underpasses that act as faunal passages to ensure no more fatalities between wildlife and road traffic occur.
3. Speed bumps should also be erected on the Voi - Taveta highway as elephants are already crossing this newly tarmacked highway and the likelihood of fatalities will increase the longer we wait for speed bumps to be built.
4. Monitoring of wildlife movements along the SGR continues for at least one more year with installation of automated cameras (camera traps) in some of the underpasses so that the impact of these management decisions can be analyzed and used for future infrastructure planning for Kenya.

About Save The Elephants

Save The Elephants (STE) is a UK registered charity (No. 1118804) founded in 1993 and based in Kenya. STE runs a range of conservation projects across Kenya, Africa and Asia to secure a future for elephants in a rapidly changing world. It is a leader in elephant science providing cutting-edge scientific insights into elephant behaviour, intelligence, long-distance movement and elephant ivory trade and applies them to the long-term challenges of elephant conservation. For more information please visit www.savetheelephants.org

About Kenya Wildlife Service

The overall mandate of Kenya Wildlife Service (KWS) since its establishment in 1990 is to conserve and manage all of Kenya's wildlife resources inside and outside protected areas for posterity and as a national heritage. KWS seeks to promote sustainable wildlife management as a viable land-use option on community and private lands. A key function of KWS is to establish linkages and gain support for wildlife conservation with stakeholders and communities co-existing with wildlife. For more information please visit www.kws.go.ke

Acknowledgements

We thank the Director general of KWS, Kitili Mbathi, for authorizing this study. We appreciate continued technical and advisory roles by Dr Samuel Kasiki, Julius Kimani, Patrick Omondi, Robert Obrien, Sospeter Kiambi, Martha Nzisa, John Wambua, Kenneth Ochieng', Cedric Khayale, Isaac Kashir and the KWS Tsavo research team. Similar roles are also being played by Frank Pope, Dr Chris Thouless, Prof George Wittemyer, Dr Jake Wall, David Kimanzi and Njoki Kibanya of STE; Elephants and Bees project team in Tsavo East; Wildlife Works team headed by Jamie Henrickson; and Tsavo Trust team headed by Richard Moller. We are forever grateful to the donors for their continued financial support.