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Reversing the disintegration of the Mara Ecosystem: A feasibility study

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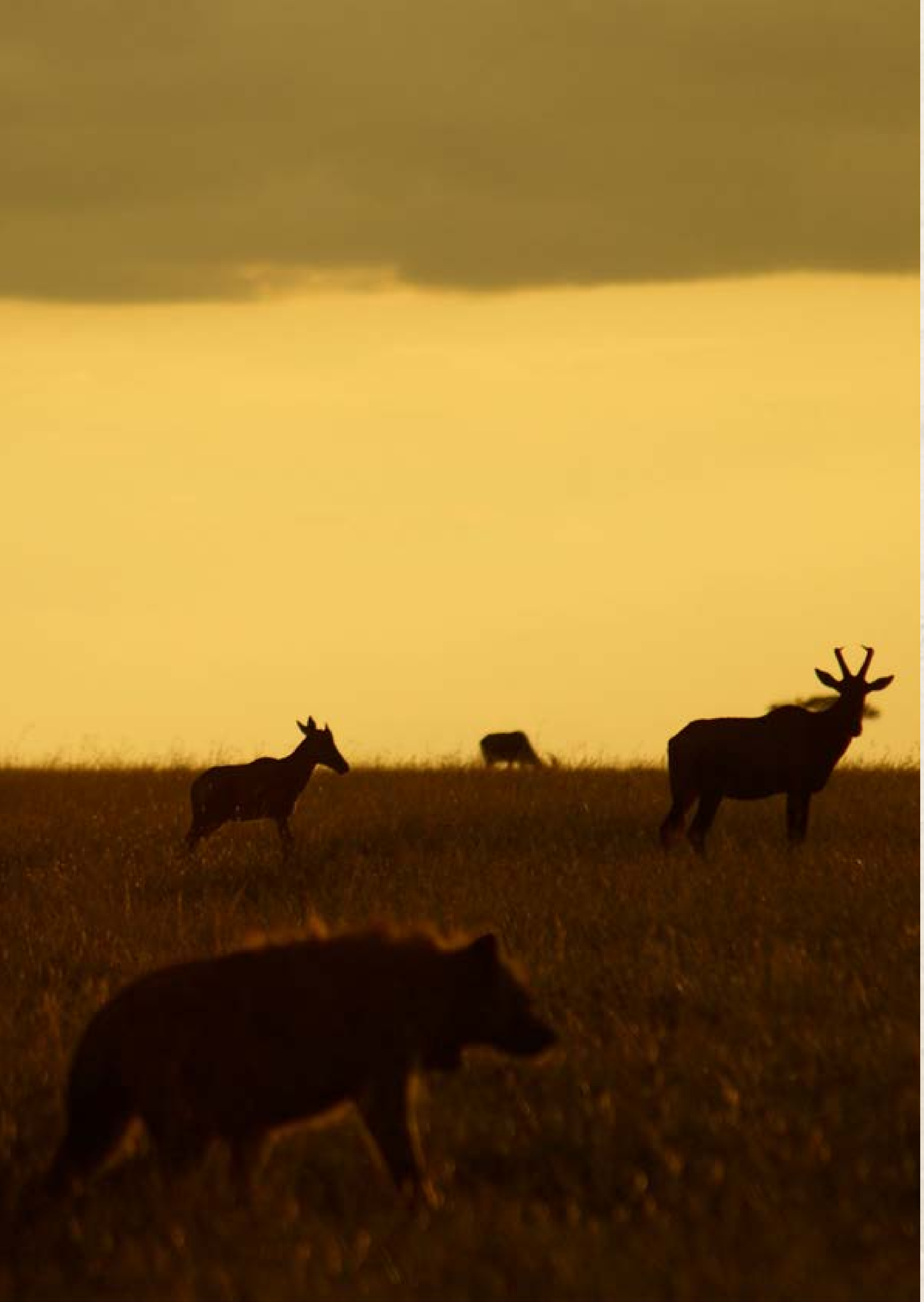
ONE MARA RESEARCH HUB

KWT KENYA WILDLIFE TRUST

Cover photo: Crossing a tributary of the Southern Ewaso Ng'iro River in the northern Loita Plains, July 2, 2019 (-1.235842, 35.703928, deg lat/longitude)



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2.0 PROJECT RESULTS

2.1 Executive summary

The One Mara Research Hub (OMRH) in May 2020 received a grant of EUR 46,000 from the Norwegian Agency for Development Cooperation (NORAD) through the Base Camp Explorer Foundation- Kenya to carry out a 6-month feasibility study of the Greater Mara Ecosystem. The aim of this study was to prioritize areas in the Mara where additional conservation areas should be established by identifying the ecologically valuable areas and mapping historical and current constraints in protecting these areas. A social survey to collect firsthand information on the views of the local communities on the impact of and need for further conservation measures was also conducted. This report summarizes, synthesizes and interprets the project's key findings and makes several first recommendations pertinent to conservation and human socio-economic development in the Mara. It should be noted that this report was a relatively short, limited study aimed at identifying the feasibility for a much more extensive project of this type.

For this study we first mapped the two migratory systems characterizing the Mara ecosystem. We then analyzed the aerial surveys of wildlife and livestock performed by the Kenyan Directorate of Resource Surveys and Remote Sensing (DRSRS) from 1977 until 2018. In this period, 75 aerial surveys were conducted where all herbivores larger than Thomson's gazelle and sheep and goats were counted in a landscape-wide 5 x 5 km grid. The results were integrated to whole-ecosystem population estimates using Jolly statistics and trends of different species over the study period calculated. Based on these data, we calculated hotspots of migrant and resident herbivores for the 1970s, as the number of species that were found in a 5 x 5 km grid cell at their 75% percentile and higher abundance (so, 75% of all grid cells for that species had a lower abundance). This yielded maps of the areas of the highest ecological importance in this ecosystem. Where the hotspots occur outside the current protected areas, such areas are candidates for new conservation measures, such as the establishment of new conservancies. We then determined the main current threats and limitations to such conservation measures, by mapping the distribution of fences from high-resolution satellite imagery, constructing a 5 x 5 km resolution human population density map, and spatially downscaling the 2019 national population census of Kenya data. Using the DRSRS data, we also mapped the changes in the abundance and spatial distribution of livestock (cattle, sheep, and goats) and resulting competitive pressure as potential explanatory variables for wildlife trends and distributions.

To get a better understanding of the views of the local communities on natural resource trends, conservation, and conservancies we interviewed 338 people with a rural livelihood (⅔rd men, ⅓rd women, all Masai). These household surveys were conducted to assess the attitudes of the Mara residents towards conservation, perception of changes, livelihoods, ranking of potential conservation-compatible development investments and impact of the Covid-19 pandemic in the Greater Mara Ecosystem. We asked 585 questions to each respondent regarding all these different aspects of their views and livelihood, and statistically summarized their responses.

In addition, we reviewed peer-reviewed journal articles, books, and gray literature, including personal memoirs, government reports, project reports and other materials, to reconstruct the recent conservation history of the Mara. The specific literature reviewed focused on wildlife abundance and distribution and land use changes in the past century with emphasis on the changes occurring within the recent decades. The review also evaluated the changes in human and livestock population, settlements, rainfall and temperature patterns, land tenure, land fragmentation through fencing and socio-cultural and political practices.

The review also considered patterns of legal and illegal exploitation of wildlife, wildlife policies, pieces of legislation, institutions, governance, and markets. Relevant datasets were amalgamated and analyzed using various off-the-shelf software packages, such as ArcGIS Online, and bespoke scripts written in different programming languages. The results are summarized as distribution maps, temporal trends, scenarios for new conservancies, constraints to, and approximate cost of, establishing each new conservancy.

2.2 Main findings

Landscape-scale mass migration of large herbivores comprising wildebeest, zebra, Thomson's gazelle and eland are well-known as a defining and unique feature of the Mara Ecosystem. But less well known is that the ecosystem was characterized until recently by two such migratory systems (Fig. 1). Both migratory systems partially overlap in their dry season range around the Mara river at the border of Kenya and Tanzania. At the onset of the wet season, a northbound migration went from here to the fertile volcanic ash area of Loita plains to find suitable calving areas. This Mara-Loita migration consisted of 100,000 - 150,000 wildebeest at the end of the 1970s.

In addition to this "Kenya's own migration", a southbound migration left at the onset of every dry season from the Mara river to the volcanic ash areas of the Serengeti Plains in the southern Serengeti National Park (SNP) and the Ngorongoro Conservation Area (NCA), both in Tanzania. The Mara-Serengeti migration consisted of 1,000,000 wildebeest in the 1970s, a migration that passed through the Ikorongo and Grumeti game reserves in Tanzania. The reason that these migrants leave the Serengeti Plains at the onset of the dry season is because this region does not have any drinking water in the dry season. These migrants first generally move to the western corridor of the Serengeti National Park, but then in July-August to the Mara river, as this is at this time the only fresh surface water left in the ecosystem, and they do not have access to Lake Victoria from the Serengeti National Park (SNP). At the most western part of the western corridor of SNP, the heavily used Nyatwali village land west of the Lamadi-Bunda roadblocks access to the lake, making the way north to the Mara River and Mara Reserve the only option for the Mara-Serengeti migrants over the last 60 years since the recovery of this migration from the rinderpest pandemic in the 1960s. An important recent development is that the government of Tanzania has decided to now include the Speke's Gulf corridor fully into the Serengeti National Park. This decision has been taken in response to concerns about the extreme wildlife declines in Kenya (including in the Mara), and the uncertainty of the Mara river continuing to carry sufficient water in the dry season due to destruction of the Mau forest. This can potentially lead to a strong shift in the migratory patterns, a reduction in the number of the Serengeti migrants visiting the Mara and their residence time in the Mara thus causing a big loss of ecotourism revenue in the Mara that is underpinned by the dry-season migration to this area (June - October).

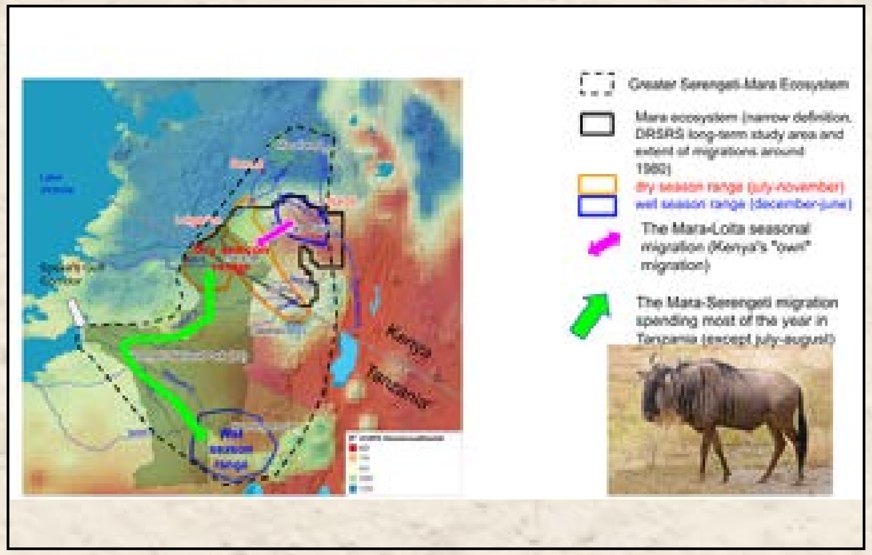

Fig. 1. Overview of the two large landscape-scale mass migrations of wildebeest that characterize the Mara ecosystem, as part of the Greater Serengeti-Mara Ecosystem spanning across Kenya and Tanzania. The white arrow indicates the Speke's Gulf Corridor area, that currently limits access of these wildebeest to Lake Victoria, driving the migration north to the Mara river in the dry season.

Trend analysis of the population numbers of the main migrants shows that all four species showed a strong ecosystem-wide decline in the wet season (Fig. 2A-D). These declines over the study period ranged from 65% (zebra) to 81 % (wildebeest). These trends could not be explained by a drying climate, as the climate got much wetter rather than drier during the monitoring period. Cattle numbers in the Mara ecosystem were strongly variable throughout the study (showing animals were moved in and out of the system depending on climatic conditions) while the density of sheep and goats strongly increased (+306%)

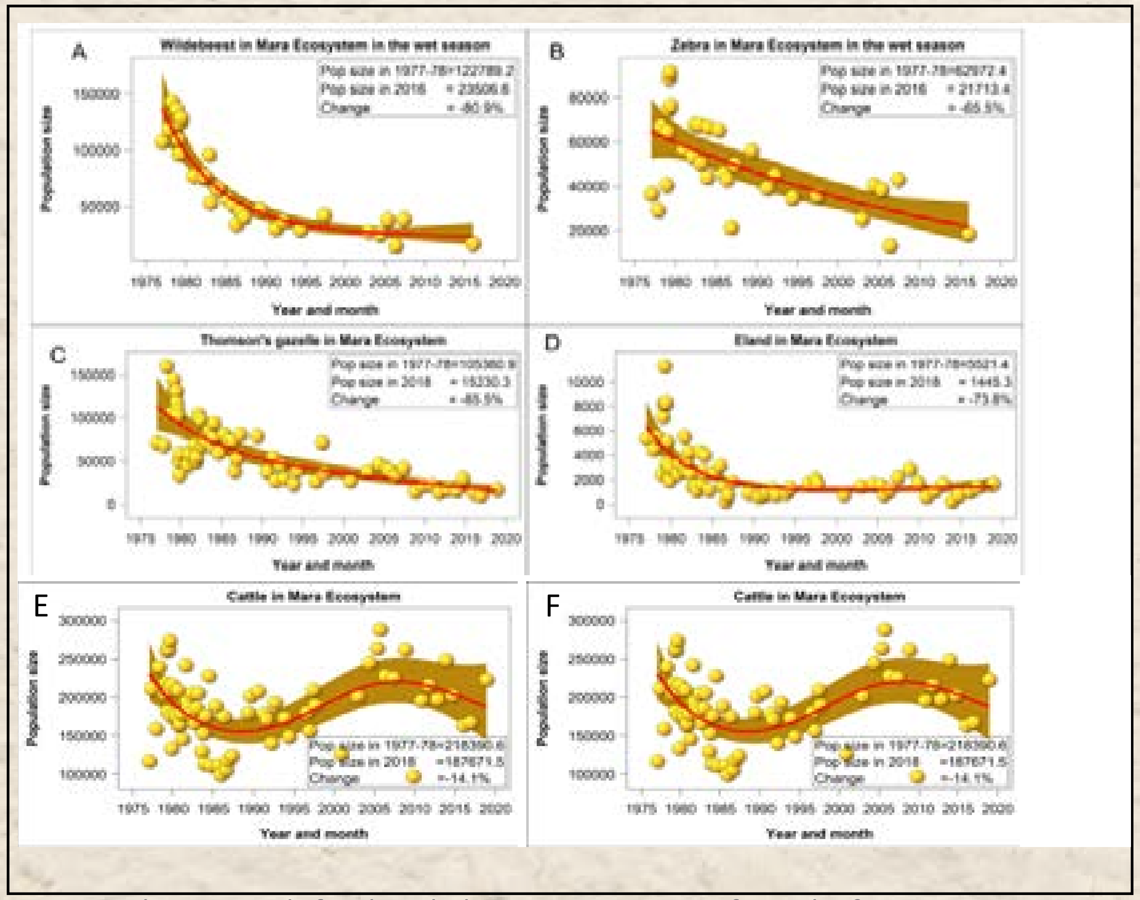

Fig. 2. Population trends for the whole Mara ecosystem of A-D the four main migrants and, E cattle and, F sheep and goats as estimated from the DRSRS aerial population surveys.

Analysis of the wet season hotspots of the four main migratory species in the Mara ecosystem (Kenya's "own" migrants) shows that in the late 1970s, the Loita plains were the prime calving areas for wildebeest, zebra, Thomson's gazelle and eland (Fig. 3A). However, this key wet season range was never protected, in contrast to the dry season range protected by the Masai Mara National Reserve and adjacent conservancies (Fig. 2A). The extensive DRSRS counts show that this multi-species migration to the Loita Plains has completely collapsed (Fig. 2B). The highest densities of these species are now found in the wet season in their original dry season range, meaning that the species stopped migrating and have been decimated or displaced from their wet season range on the Loita Plains (Fig. 3B).

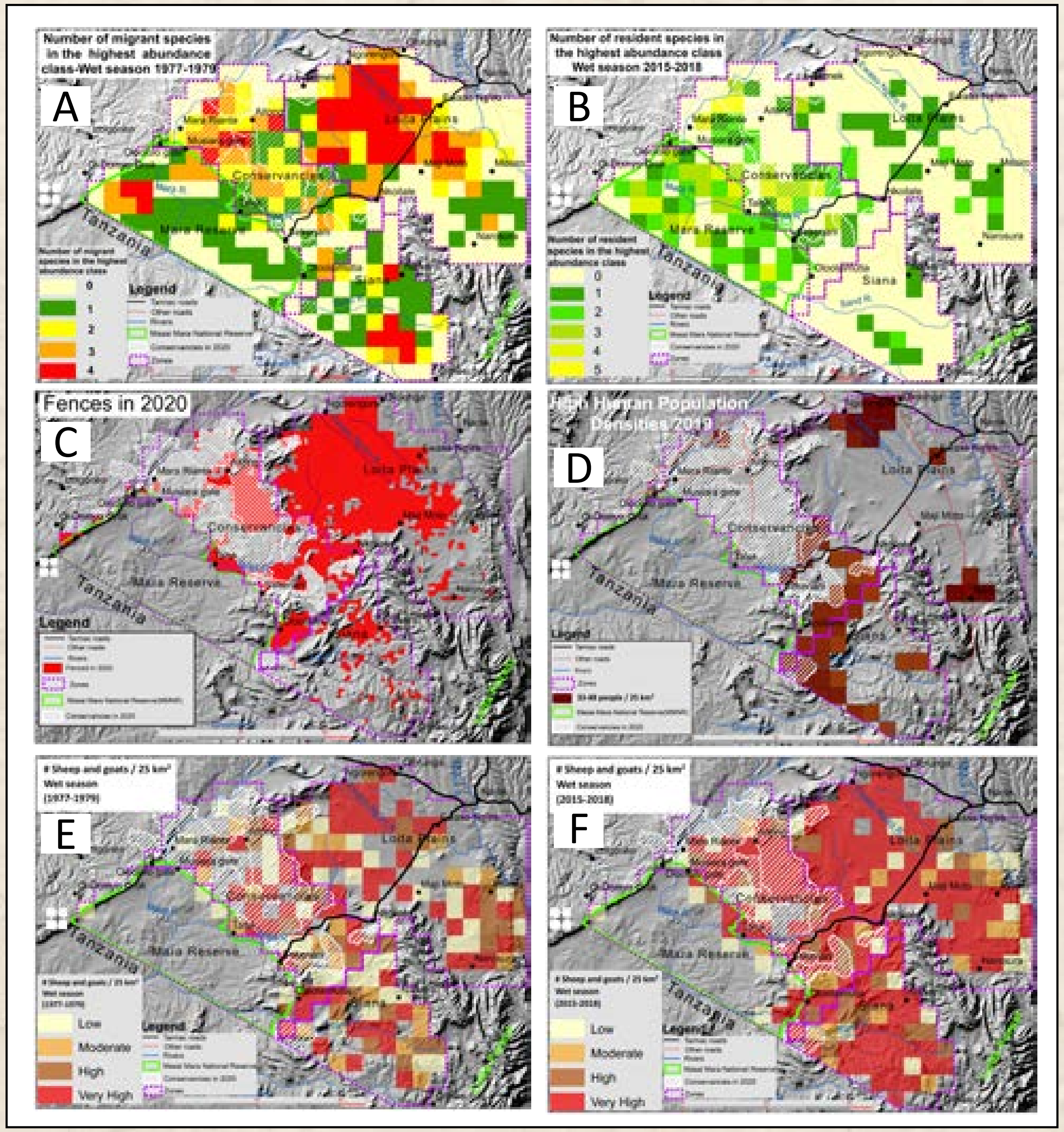

Fig 3. Changes in hotspots of abundance of the main migrant species (wildebeest, zebra, Thomson's gazelle, eland) from A) the late 1970s to B) the last 5 years, in relation to C) the current distribution of fencing, D) human population density and E, F) changes in the abundance of sheep and goats as inferred from aerial surveys. The redder the color of the migrant hotspots, the more species were found at that location at their highest abundances.

In addition, a wet season hotspot of migrants was found in the Olposimoru area in southeast Siana close to the border of Tanzania (Fig. 2A), potentially reflecting an additional migration using the Loliondo highlands in Tanzania as their dry season range or partially large resident herds. Long-term residents stated that they are aware of a migration that historically involved wildebeest movements from the Loita Plains through Narosura to the Olposimoru Plains on the Kenya-Tanzania border and Loliondo highlands in Tanzania. The collapse of the main migration from the Mara river to the Loita Plains (Fig. 2A) is associated with a strong recent expansion of the fencing of land after its privatization and subdivision (Fig. 2C). At this moment, the original calving area of the Loita migration is completely fenced for livestock, and so is not accessible for migration anymore (Fig. 3A). In addition, a strong increase in sheep and goats may have additionally contributed to the disappearance of the Mara-Loita migration (Fig. 2 E, F), but also to the strong decline of wildlife in conservancies such as Mara North where fencing does not play a role (Fig. 2B). The exponentially increasing abundance of sheep and goats (Fig. 2F) leads to increasing competition for food and direct displacement through disturbance, and indirect effects through vegetation change towards less palatable plants.

We conclude therefore that human activities, such as human population increase, changes in land tenure, greater preference for small livestock rearing and potentially also increased tourism activities, seem to have had adverse effects on the landscape connectivity. We assess that improved infrastructure such as the tarmacking of the Narok-Sekenani road, and the subdivision and subsequent fencing of land parcels are the main proximate drivers of the loss of landscape connectivity, which is directly affecting the migrations in the ecosystem.

In the Conservancies zone of the landscape, the willingness of people to rent out land to conservancies is generally high, and this interest is also shared with 1/3rd of the respondents in the Loita Plains (despite their lack of experience with conservancies). In the conservancies zone, the majority of respondents (75%) were willing to remove fences to form new conservancies, and 37.5% of the respondents in the Loita Plains were also willing to remove fences (Fig. 4)

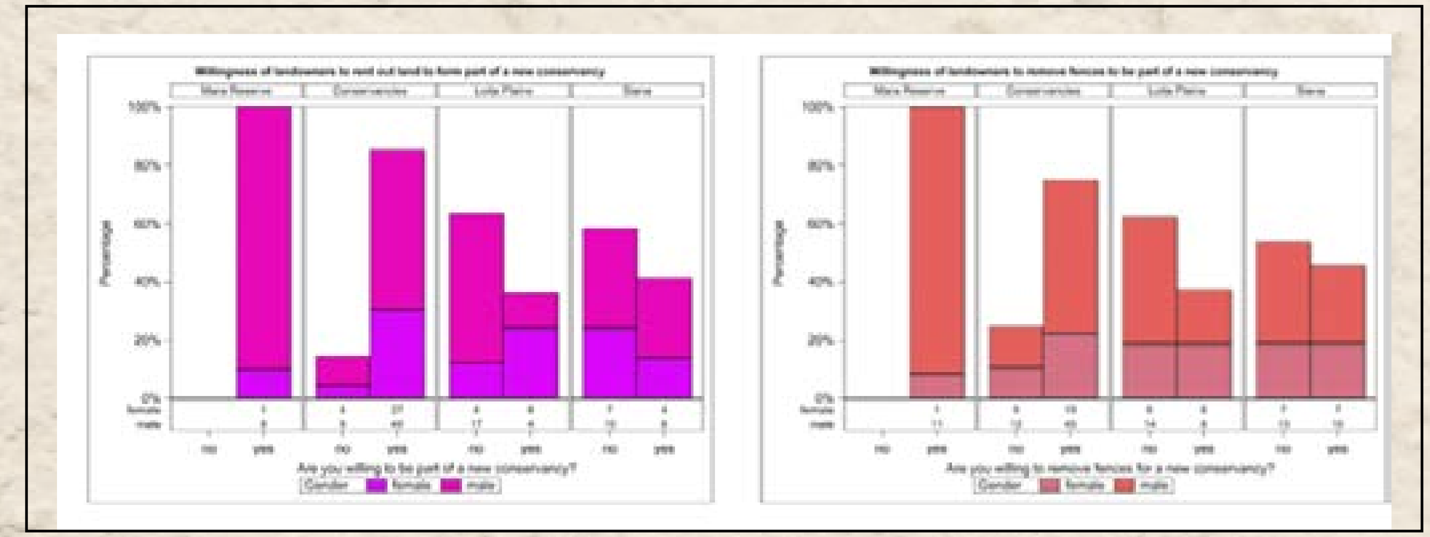

Fig. 4. Results from the household interviews in the four landscape zones on A) the willingness of the people to rent out land to form a new conservancy and B) to remove fences to form a new conservancy.

The household surveys thus showed a significantly positive attitude towards conservation, especially regarding the formation of conservancies since 2005. Though the major income earning activity remains livestock rearing, many respondents indicated conservancies and tourism as also significant income sources. The report discusses the results of the survey in more detail. Findings of the household survey and from analyses of wildlife and climate monitoring data are used as the basis for recommendations and development of scenarios for new wildlife conservancies.

2.3 Preliminary recommendations on new conservation measures

Due to the limited time available for this study, we did not do extensive scenario studies for alternative land use options to counteract the strong wildlife declines in the Mara. But we developed some preliminary scenarios as ‘proof of concept’ using the extensive wildlife monitoring, remote sensing and household survey data presented above. These scenarios all aim at 1) restoring a sufficiently large part of the calving range in the wet season for wildebeest, zebra, Thomson’s gazelle and eland, and 2) creating a corridor that would allow the animals to reach this restored wet season range from their current sedentary range (their former dry season range). If achieved, this restored wet season range has the potential to ‘bend the curve’ and create an upward shift of the currently strong downward trends in the populations of all species for this ecosystem (Fig. 2A-D). When combined with sustainable livestock grazing, this changed land use also has the capacity to increase the resilience of livestock keepers to cope with climate change. The rainfall in the Mara is cyclic with dry and wet periods alternating in a 6-10 year cycle. When the current wet phase of these cycles comes to an end, likely within 5 years, the current land use (full sedentary ranching with extensive artificial water points) can have catastrophic effects on livestock, the ecosystem, and livelihoods of the people. Restoring the multi-species Mara-Loita migration would likely also help restore populations of the other wildlife species.

We envision six different scenarios for new wildlife conservancies in the Mara and the approximate cost of each were developed based on insights gleaned from the data analyses. Below, we first describe each scenario and then tabulate the approximate cost of creating the new wildlife conservancy proposed under each scenario.

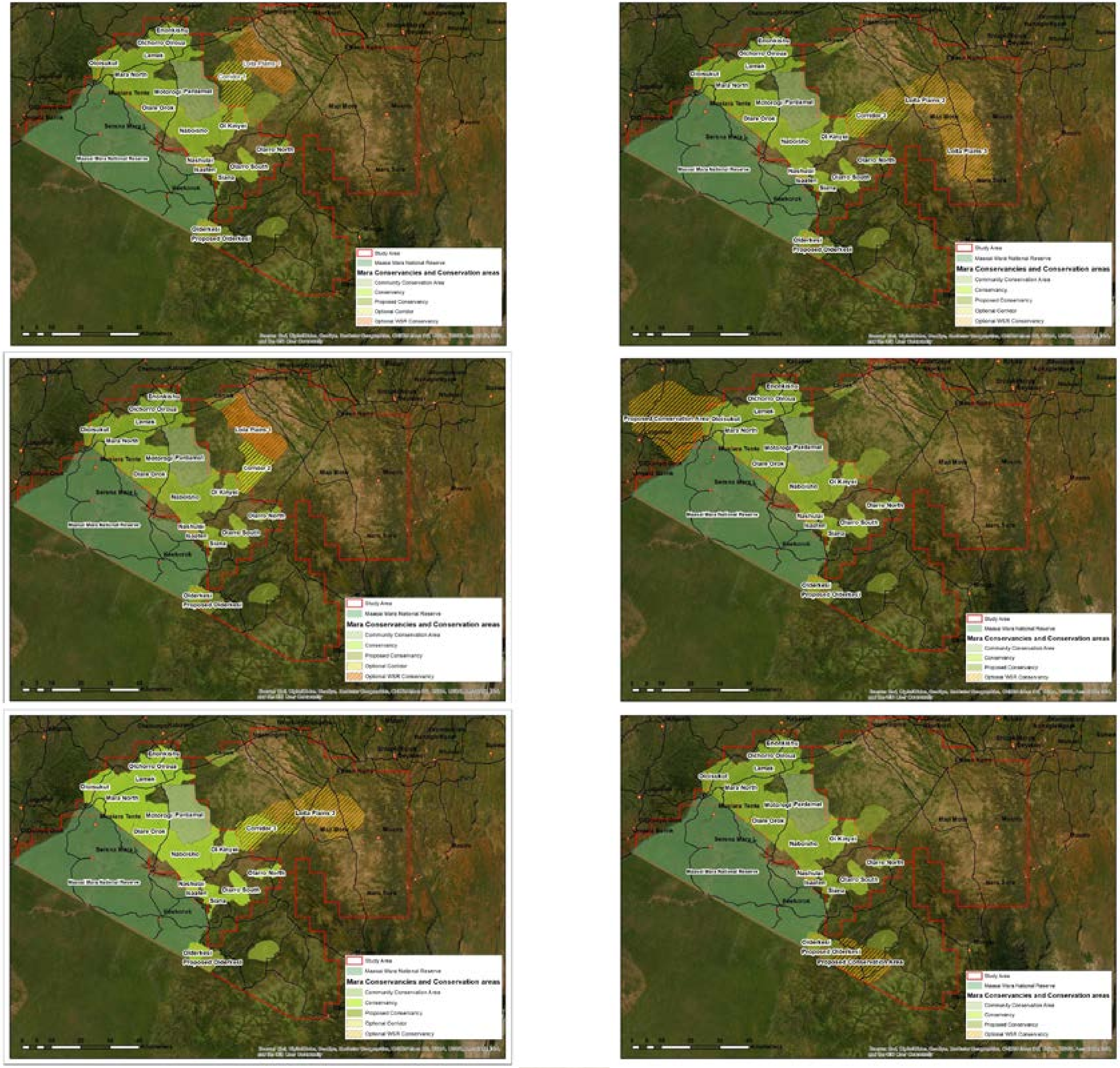

Fig. 5. six different scenarios for new protected areas aimed at the restoration of the wet season range of the Mara-Loita migration, as shown in Fig. 2A. Each scenario contains a wet season core calving range area (in red) and a corridor through which the migrants can reach these areas (in orange). The areas indicated in green are the current protected areas. See the main report for a larger version of these maps.

Scenario 1 involves the establishment of a new protected area of 256 km² (approximately 27 x 9 km) in the previous primary wet season calving area of wildebeest in the Loita Plains. The area connects from the current Mara Insinya conservancy, a protected area situated on a hilly area just adjacent to the Loita Plains and ends 4 km before the Narok-Sekenani main road. The area can be a viable wet season range for at least 10,000 wildebeest again if all current fences (see fig 3c) are removed. For this area to function again as a wet season range, it needs to be connected to the current conservancies (the dry season range) with a corridor.

Scenario 2 involves the same wet season range protected as Loita Plains 1 in the previous scenario but connected to the current Ol Kinyei conservancy through a different corridor of 266 km² (Corridor 2, fig. 2). This corridor mostly overlaps with the Muntoroben community conservancy area that is considered by MMWCA, which may increase its feasibility.

Scenario 3 involves the proposition of a different protected area for the Loita Plains wet season calving area: a 699 km² area situated between Maji Moto and Ewaso Ng'iro, situated left and right from the main Narok-Sekenani road. This scenario could make the Maji Moto town into a new tourism hub associated with this conservancy but will necessitate restrictions on its further expansion (buildings, power etc) as historic movement analysis show that the migrants clearly stay away from busy settlements.

Scenario 4 involves an expansion of the previous scenario with an additional protected area in the Loita Plains stretching more south towards Narosura. This Loita Plains 3 area has a large advantage that it is not yet subdivided, and fencing is just starting in this area. This may lead to greater susceptibility of the landowners for alternative scenarios towards the use of the land and associated income. However, due to its geographic position, this wet season range can only be connected to the dry season range through the realization of the previous scenario.

Scenario 5 deviates from the other scenarios by proposing a conservation area encompassing Nyakweri Forest, covering approximately 523 km². This area is an active Elephant hotspot and crucial water tower, which highlights its ecological importance. Currently, the forest is being somewhat protected, but is under threat from subdivision and thus fencing in the south, adjacent to the Maasai Mara National Reserve. There is a road passing through the proposed area which would strain wildlife crossing. There is also increased deforestation for charcoal production and fencing poles that directly threatens the forest, and thus highlights the need for it to be more intensively conserved.

Scenario 6 looks at the possibility of a conservation area or corridor by the Proposed Olderkesi Conservancy which covers an area of approximately 197 km², which is an important route that connects Elephants from the Maasai Mara National Park and Mara conservancies to the Loita Forest. The population density of this area is significant in comparison to other areas suggested in the previous scenarios, but data shows that fencing is minimal, and thus the cost of fence removal would be lower than other scenarios. However, this area has a high density of livestock, which may influence community attitudes towards adopting conservation as an alternative or secondary livelihood. The already existing proposal to extend Olderkesi suggests an already positive attitude towards conservation in this area, which may make the adoption of this scenario easier in comparison to previously mentioned scenarios.

2.4 Rapidly growing towns in the heart of the Mara ecosystem

In addition to securing the necessary funding and community support, there is another current key threat to sustaining the biodiversity of the Mara ecosystem through these scenarios. In the heart of the Mara ecosystems five towns (former shopping centres and gates) are now very rapidly growing: Mara Rianta, Talek, Sekenani, Oloolaimutia and Nkoilale (Fig. 5b). Their growth is spurred by the recent infrastructure improvements: the tar road from Narok-Sekenani and the improved road from Narok - Mara Rianta, which is earmarked for tarmacking. This leads to growing problems with drinking water, pollution from sewers and overall wildlife disturbance, impairing the promise of future ecotourism revenues that accelerated the development of these towns in the first place. Spatial planning is urgently needed to evaluate and potentially control these rapid developments.

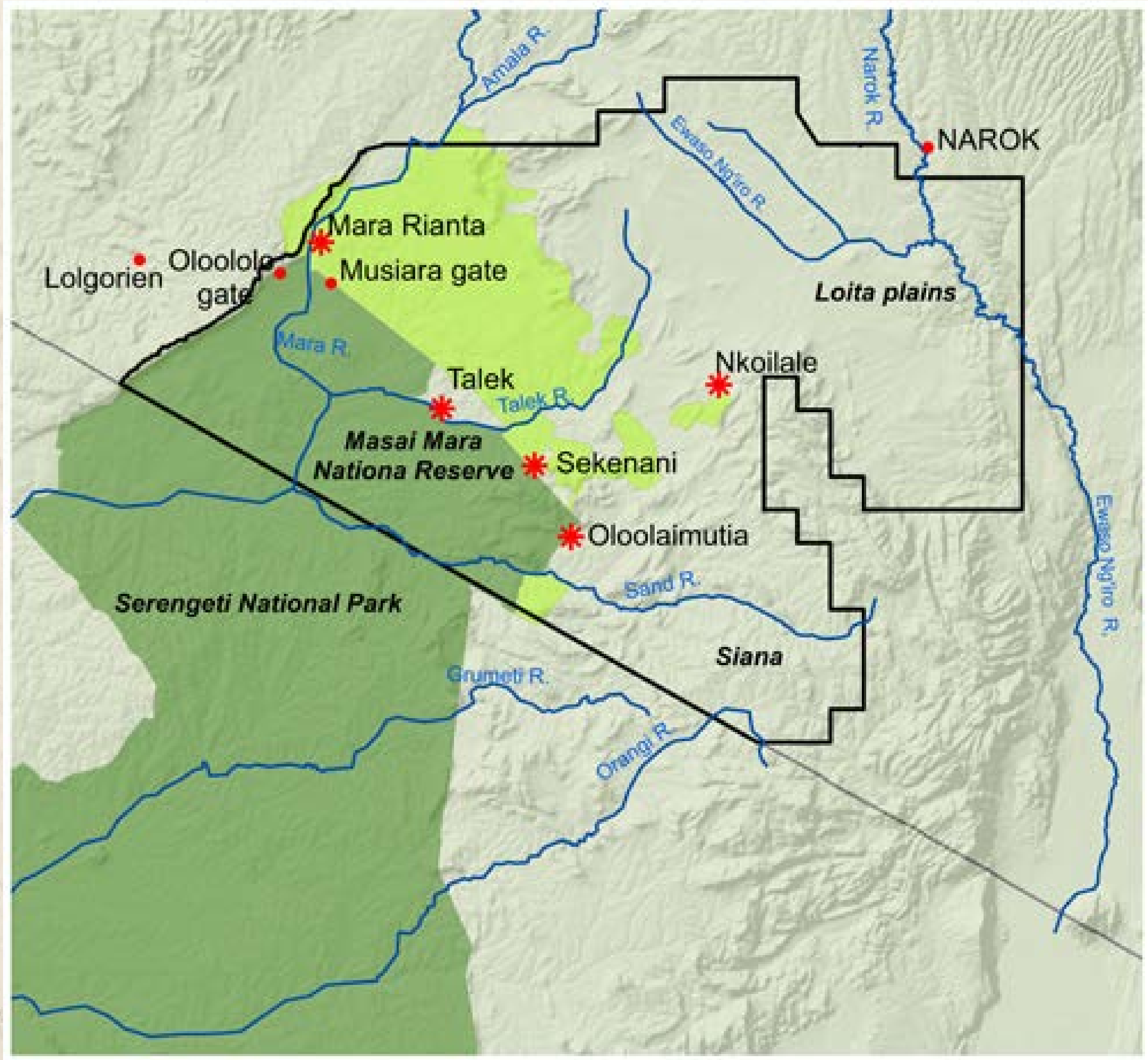

Fig. 5b: Five rapidly growing towns in the heart of the Mara ecosystem.

2.5. What's next?

Regarding the follow up now needed, table 2 outlines the three important next steps that the research team envisages as necessary and urgent. First, the current feasibility study should be extended to result in a detailed project plan. Then, the funding for the project implementation based on the project plan should be secured. Finally, the project should be implemented as soon as possible.

Table 1: Necessary steps in project development to restore migration to the Loita Plains and bend the curve of current biodiversity loss in the Mara Ecosystem

Phase	Main deliverable
a. Feasibility study (this study)	Explore the feasibility of a project aimed at restoring the northern migration and associated biodiversity and livelihood improvement
b. Project plan development with stakeholders and scientific underpinning	Develop a full and detailed project plan for restoring the northern migration to the Loita Plains and associated livelihoods of people, with extensive stakeholder involvement (land owners, authorities, conservation organizations, tourism industry), scientific analysis of the deeper causes of wildlife decline (importance of climate change, livestock, markets, socio-cultural factors, policy, governance, law enforcement, land tenure change, human population growth, infrastructure development, institutions) to develop long-term solutions, expected biodiversity benefits, economic feasibility study, sustainable business model, governance model, and recommended scenario of choice, organization and presentation of all information in online spatial web mapping and planning tools. The proposal here is to continuously monitor the ecosystem to establish a baseline, indicators and assess changes in the ecosystem. First cost estimate: 1 million Eur.
c. Secure the funding for the project plan	Using the detailed project plan, this phase regards the securing of funding for the implementation phase of the project. Funding will focus on continuous assessment of the ecosystem and working towards securing corridors and conservation areas.
d. Project plan implementation	Implementation phase of the recommended scenario: establishment of a corridor and wet season range protected area at the Loita Plains

It is crucial to continue the DRSRS aerial monitoring surveys in the Mara ecosystem in the wet and dry seasons to assess the effects of the Covid-19 pandemic on wildlife and livestock. This would also allow an assessment of the status of wildlife, livestock, and their habitat condition as a reliable basis for the development of the Mara ecosystem management plan and the Narok County Spatial Plan. One DRSRS aerial survey in the Mara ecosystem costs approximately USD 35,000. Aerial surveys are badly needed for the 2021 wet and dry seasons as the last surveys were conducted in 2018 and no aerial monitoring has been conducted ever since.

3. MAIN REPORT

3.1. Scope of the Report

The One Mara Research Hub (OMRH) received a grant of NOK 500,000 from NORAD through Base Camp Explorer Foundation- Kenya, in May 2020 to carry out a feasibility study into identifying and prioritizing areas in the Mara where additional conservation areas can be established and the potential constraints to doing so. Recognizing that conservation should focus on people to be a successful and integral component of development, the study also explores options for sustainable and conservation-friendly investments aimed at improving community livelihoods across the Mara. Lastly, the study assesses the Mara communities' social, demographic, land tenure and other characteristics, as well as dominant spatio-temporal trends in the Mara. This report summarizes, synthesizes, and interprets the study's key findings and makes recommendations pertinent to conservation and human socio-economic development in the Mara.

3.2. Introduction

The Mara-Serengeti Ecosystem is arguably one of the Earth's most important and iconic ecosystems. It is home to the world's largest remaining migration of terrestrial large mammals and exceptional abundance and diversity of animal and plant species. The ecosystem covers about 40,000 km² astride the international border of Kenya and Tanzania. The northernmost section of the ecosystem, the Greater Mara Ecosystem (Mara), encompasses 7,500 km² of Narok County (17,921 km²) in southwestern Kenya. The Mara is Kenya's finest, most popular, and successful wildlife viewing area. Crucially, it supports almost 30% of Kenya's wildlife. Yet, the Mara is experiencing extreme loss of wildlife and their habitats, making it imperative that immediate, decisive, and far-sighted steps be instituted to save the wildlife and their habitats. The remedial measures should be immediate because the window of opportunity to restore wildlife populations and their habitats is fast closing given the types, rates and scales of the changes occurring in large parts of the Mara.

The future of the Mara is in imminent and grave jeopardy because its spectacular wildlife, the prime draw card for tourists, is disappearing relentlessly and fast. Wildlife has been declining strikingly and persistently in the Mara since the Directorate of Resource Surveys and Remote Sensing of Kenya (DRSRS) began regular aerial monitoring in 1977. All large wildlife species, save for elephants that are increasing largely because they enjoy exceptional protection, are declining at alarmingly high but comparable rates inside and outside the protected Masai Mara National Reserve (Reserve) and the semi-protected adjoining wildlife conservancies, established since 2005. The exceptional protection afforded to elephants has unfortunately not helped save the other co-occurring wildlife species contrary to the popular belief that elephant is a keystone species whose protection would automatically translate into similar protection of the other co-occurring species.

The declines can be attributed to dynamic, multi-layered, and manifold processes, some of which have been sequential and dominant at different times, whereas others have been concurrent. The dominant processes reflect the systemic failure of Kenya's national wildlife conservation and management policies, legislations, institutions, governance, and markets. The effects of these failures are compounded by those of exponential human and livestock population growth, overexploitation of wildlife and destruction of their habitats, the tragedy of government-instigated land privatization through subdivision since 1954 that drives fencing, land use, climate, and socio-cultural changes. Consequently, the disturbing loss of wildlife and their habitats can be linked to processes in both time and space. Notably, the rate of wildlife decline has been accelerated by land privatization in large parts of the Mara from 2000 onwards, and the associated land subdivision and fragmentation through fencing, most especially from 2013.

The unprecedented expansion of fence wires driven by individualization of land tenure has exacerbated wildlife declines by displacing them most especially from their critical wet season ranges, blocking their seasonal migration and dispersal routes, access to watering points, or directly killing animals entangled in fences. Furthermore, an increase in both the wet and dry season rainfall components linked to the Indian Ocean warming and coincident with the wet phase of a 6 to 10-year cycle in local rainfall has additionally stimulated fencing by creating transient conditions suitable for sedentary livestock ranching and crop farming.

The wildlife policy, institutional and market failures include the fact that the Kenyan government denies private landowners' user or ownership rights over wildlife; banned all forms of consumptive wildlife utilization in 1977; withdrew wildlife rangers and wardens; and dismantled ranger posts from private lands in 1977. Consumptive utilization was re-introduced in a few areas in 1992 and discontinued in 2002, demonstrating policy vacillation and unpredictability, largely due to weak law enforcement. Moreover, private landowners receive no compensation for the forgone opportunity of producing government wildlife on their private land. Compensation for wildlife damage to property, human injury or death exists in law but is hard to receive in practice.

The main governance failures relate to the dismantling of traditional Maasai institutions for commons management and concentrating wildlife conservation and management responsibility in a monolithic and grossly underfunded national wildlife conservation and management institution, plus decades of economic marginalization of pastoralists. The latter has relegated pastoralists to the periphery of economic development for decades. In consequence, pastoralists count among Kenya's poorest of the poor, and are highly dependent on extraction of natural resources to support their livelihoods. This can inevitably be expected to have significant adverse environmental impacts as human population increases and infrastructure development expands. What is more, wildlife conservation and management in Kenya is primarily through command and control, which does not work on private lands. The massive losses of wildlife and their habitats in the Mara, and elsewhere in Kenya's rangelands, also mirror another fundamental weakness of wildlife conservation and management in Kenya: the total lack of spatial and ecosystem level planning as well as the lack of deep commitment to implementing policies and plans in the rangelands yet they constitute 88% of Kenya's land surface and support over 65% of all Kenya's wildlife.

Another persistent problem is the continuing slaughter of considerable numbers of wildlife as part of "problem animal control", a practice dating back to the beginning of the former Kenya Game Department in 1901. Yet another important factor contributing to wildlife losses is underfunding of wildlife conservation and management as only a small percentage of the total national tourism revenue, supported mostly by wildlife ecotourism, is reinvested in wildlife conservation.

Wildlife conservancies have proven, perhaps, the most successful contemporary private or community institutions to reclaim space and place (in the livelihood of landowners) for wildlife in the unprotected private lands that support over 65% of Kenya's wildlife. They are stepping in to fill the vacuum left after game rangers and wardens deployed outside Kenya's parks and reserves were almost all withdrawn after the merger of the Kenya Game Department and the Kenya National Parks in 1976 to form the Wildlife Conservation and Management Department (WCMD). It comes as no surprise, therefore, that conservancies have become a very popular vehicle for keeping open space for wildlife on private or community lands in arid and semi-arid Kenyan rangelands. Conservancies currently (2020 update in progress) cover about 18% of Kenya's land surface and nearly 1,500 km^2 of the almost 6,000 km^2 of private lands in the Mara and support over 700,000 families across Kenya.

The Mara ranks among the premier ecosystems in Kenya where conservancies have been established and managed with some success since 2005, primarily because of a high tourism potential. There, therefore, exists a huge potential for expanding conservancies to include parts of the remaining unprotected areas in the Mara. Yet, despite their establishment and expansion since 2005 and successes in many other spheres, the aerial monitoring data shows, unequivocally, that the conservancies have evidently not succeeded in enabling an overall increase in wildlife numbers in the Mara. Why? We think the main reason is that the conservancies are protecting mainly the dry season concentration area and not the equally important wet season feeding and calving grounds for many of the species. It follows, logically, that expanding conservancies to include large parts of the wet season grazing and breeding ranges of the Mara-Loita migratory wildebeest, zebra, Thomson's gazelle, and eland; Kenya's last mass migration, currently on its deathbed, should, undoubtedly, be an urgent and topmost local and national conservation priority.

This report synthesizes and interprets the major changes taking place in the Mara, their historic, contemporary, and likely future consequences. It provides quantitative characterization of these changes and insights into salient local community demographics, livelihoods, views, and perspectives that can guide efforts to save the Mara ecosystem while also enhancing human livelihoods. We first define the Greater Mara Ecosystem, then summarize the methods and approaches used in the study, present results of trend and scenario analyses and briefly review findings of previous research and conservation history of the Mara.

3.3. What is the Greater Mara Ecosystem?

There is no single, generally accepted definition of the Greater Mara Ecosystem (GME). This is because the boundary of the ecosystem has been changing over time owing to human land use developments within and outside its borders. Here, we offer both broad and narrow definitions of the GME. The broad definition includes the Mau forest that forms the headwaters of the Mara river plus the area used historically by migratory wildebeest up to around 1880 (Fig 6,7). The GME is an inseparable part of the Greater Mara-Serengeti ecosystem that spans the international boundary of Kenya and Tanzania (Fig. 8) that is used by the Great Wildebeest Migration and traversed by the Mara river. Clearly, the entire ecosystem ought to be viewed and managed as one large, transboundary ecosystem.

The narrow definition of the ecosystem is the more widely used in practice and is based on the extent of the area used by the local wildlife migrations up to around 1980 and covered by the long-term aerial monitoring surveys carried out by the Directorate of Resource Surveys and Remote Sensing of Kenya (DRSRS) since 1977. There are strong rainfall and soil fertility gradients in the GME that drive the large seasonal migrations of the Mara-Loita wildebeest, zebra, Thomson's gazelle and eland. The dry season range of this migration is presently restricted mostly to the protected areas formed by the Mara Reserve and the adjacent conservancies. But the crucial wet season range in the Loita Plains does not have any protected area (Fig 7). The Mara-Loita migration, also called the northern migration, is NOT the same as the spectacular migration that crosses the Mara river into the Mara Triangle in the Mara Reserve from the Serengeti National Park in Tanzania. The animal groups involved in the latter migration are part of a different migration: the Mara-Serengeti Plains migration, also known as the southern migration. These animals use the Serengeti Plains in Tanzania as their wet season calving range whereas the Mara-Loita migrants historically calved on the Loita Plains (Figs 8).

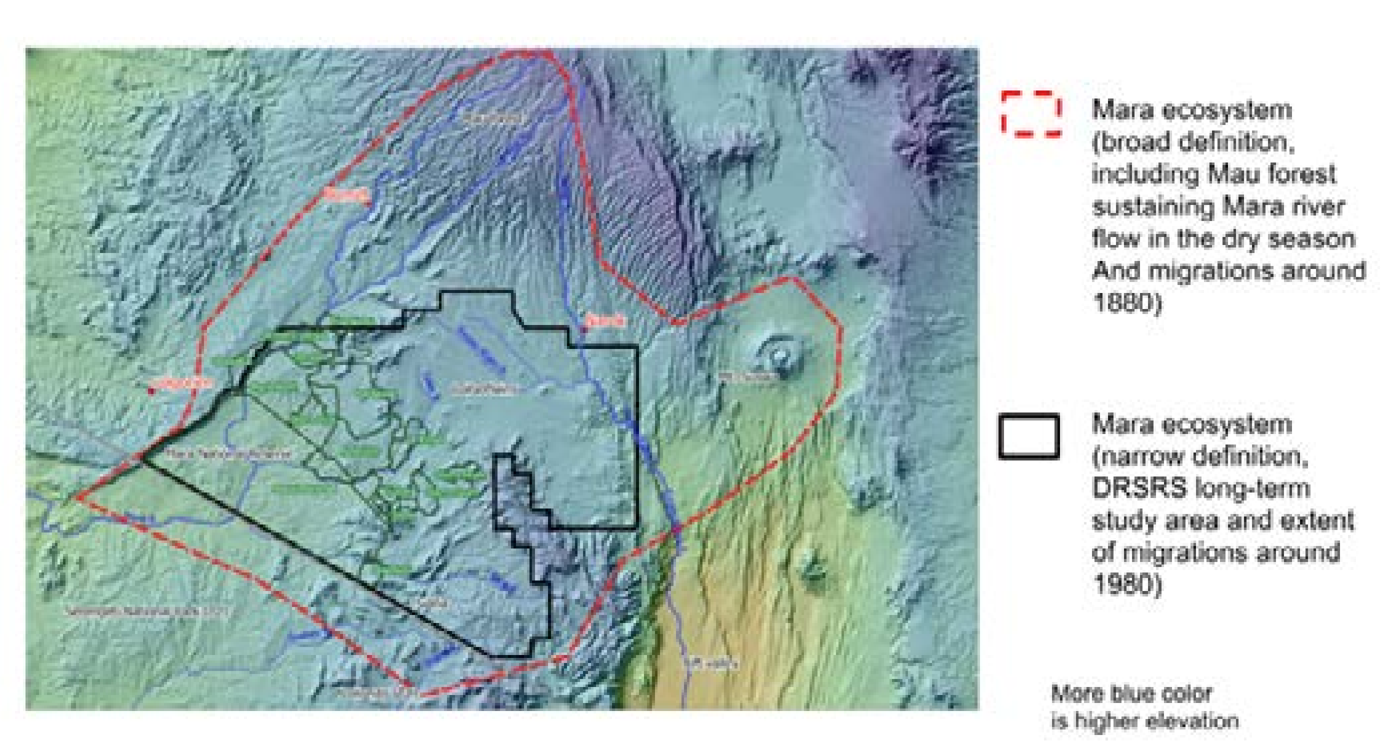

Fig. 6 Outline of a broad and a narrower definition of the Mara Ecosystem.

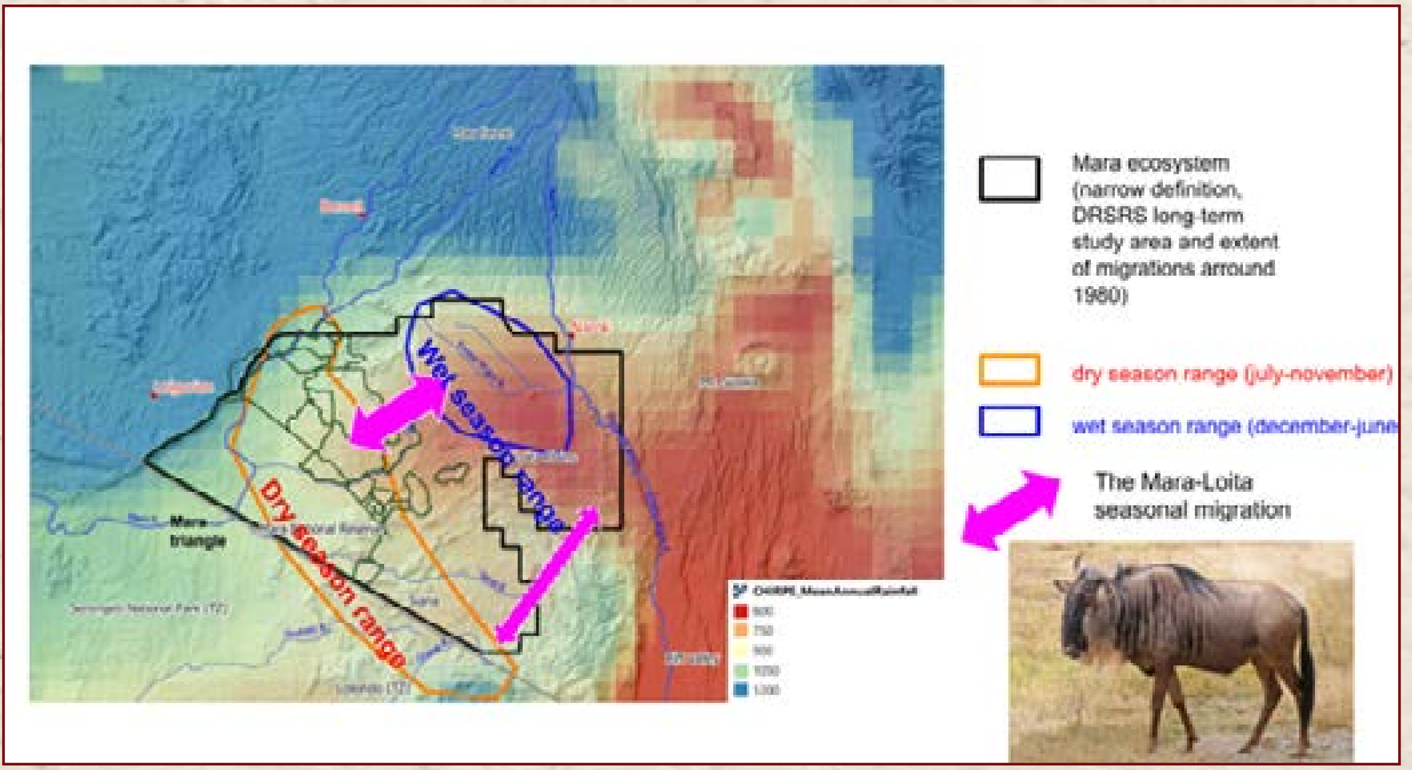

Fig 7. Main migratory movements of wildebeest and zebra in the Mara ecosystem in the late 1970s

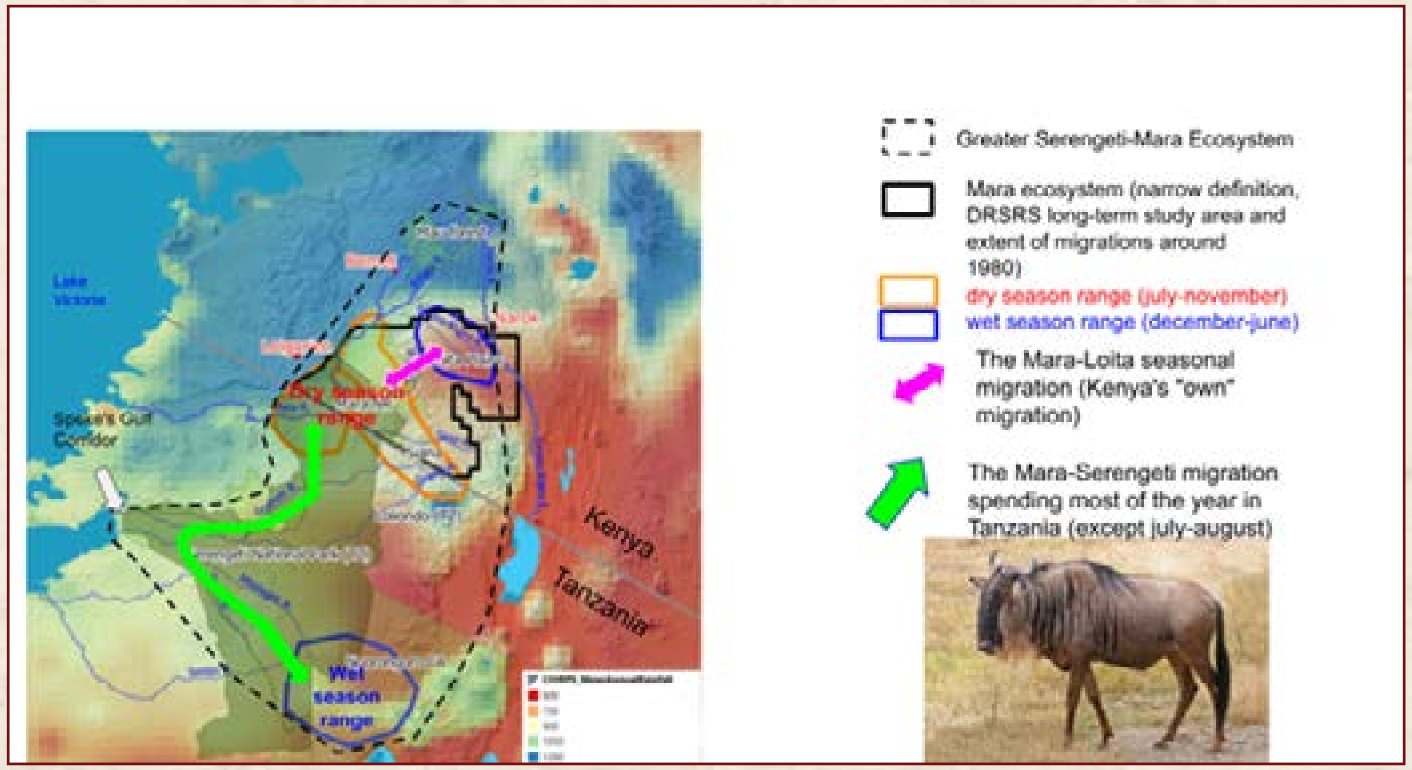

Fig 8. Overview of the two large landscape-scale mass migrations of wildebeest that characterize the Mara ecosystem, as part of the Greater Serengeti-Mara Ecosystem spanning across Kenya and Tanzania. The white arrow indicates the Speke's Gulf Corridor area, that currently limits access of these wildebeest to Lake Victoria, driving the migration north to the Mara river in the dry season.

3.4. Definition of the four study area zones

For this study we use the narrow definition of the Mara ecosystem (black line in Fig. 6) that covers an area of some 7,500 km² used by the Mara-Loita wildebeest, zebra, Thomson's gazelle, and eland migrations during 1977-1982, based on 75 aerial surveys conducted by the DRSRS. From the perspective of the Mara-Loita migration, we subdivided the Mara ecosystem into four zones comprising: the Masai Mara National Reserve (1527.89 km², an area slightly larger than the official reserve area of 1510 km²), the Conservancies zone adjoins the reserve to the north (1750.05 km²), Loita Plains (2397.05 km²) and Siana (1200.38 km², Fig 9). It should be noted that the Conservancies zone also contains smaller areas (along the road to Sekenani, or around Oloolaimutia) that are not protected as conservancies.

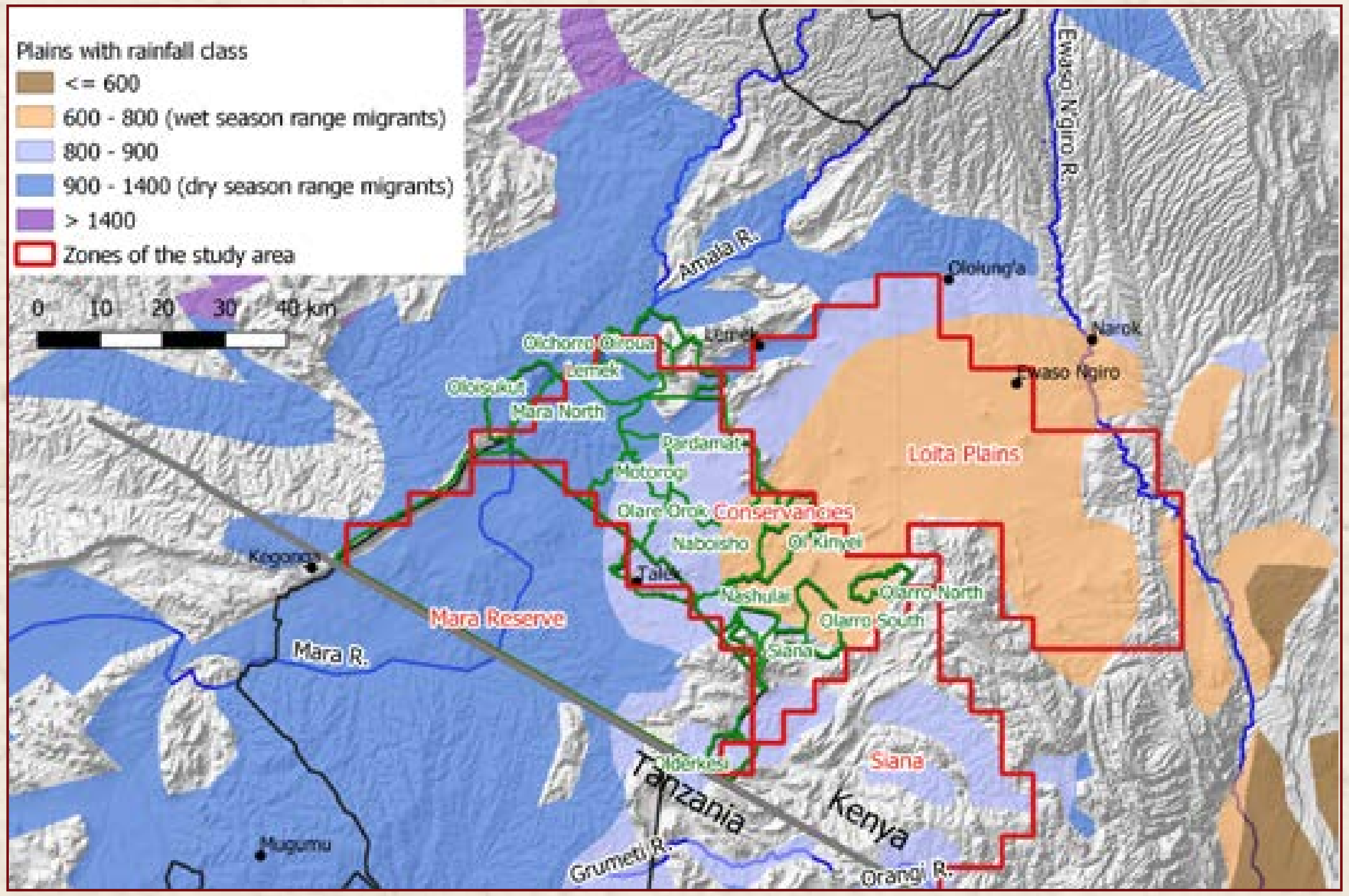

Fig 9. Overview of the main plains habitat (colored areas) with their rainfall gradients in the Serengeti Mara. Plains habitat - important for migrants such as wildebeest and zebra - is shown in three rainfall classes, reflecting the dry season range (dark blue), transitional area (light blue) and wet season calving areas (orange). The distribution of the current protected areas is shown in green colour. The four zones comprising the Mara reserve, Conservancies, Loita Plains and Siana are also shown.

3.5. Methods and approaches

We analysed trends in the population size of 14 common wild herbivore species, the size of Thomson's gazelle (15 kg) and larger, and the four common livestock species (cattle, sheep and goats and donkey), using 75 aerial survey monitoring datasets collected by the Directorate of Resource Surveys and Remote Sensing of Kenya (DRSRS) in the Mara ecosystem from 1977 to 2018. The aerial surveys used the same systematic reconnaissance flight method for consistency and 5 x 5 km or 5 x 2.5 km spatial resolution, enabling monitoring of changes in both animal population size and spatial distribution. We estimated the total population size for each wildlife and livestock species using Jolly's method 2 for unequal length aerial transects. Each 5 x 5 km spatial unit was classified as a hotspot of abundance for a given wildlife species (migratory or resident) if the abundance of the species in the unit in a particular year was not less than the 75th percentile of the frequency distribution of all the abundance estimates for all the units for all the 75 aerial surveys. By contrast, a 5 x 5 km spatial unit was classified as a hotspot of species richness in terms of the total number of different species (migrants or residents) that had abundance estimates not less than the 75th percentile in the unit. We also analysed trends and distributions of several potentially important drivers of changes in wildlife and livestock numbers in the Mara ecosystem. First, we analysed trends in human population size and distribution by down-scaling, from the sub-locational to the 5 x 5 km spatial resolution, Kenya National Bureau of Statistics (KNBS) national censuses for 1962, 1969, 1979, 1989, 1999, 2009 and 2019. Second, we mapped the distribution of fences and how this changed over time at 1 x 1 km spatial resolution using remote sensing data combined with ground-truthing. More precisely, we used Landsat 5 imagery to map the presence or absence of fences in 1 x 1 km pixels from 1985 to 2010 and Sentinel-2 imagery at 10 m resolution from 2012 to 2020. Regional manifestation of global climate change in the Mara was analyzed by modelling trends in the wet and dry season rainfall, minimum and maximum temperatures from 1965 to 2020.

To capture the demographics, livelihoods, views, and perceptions of the local communities on conservation, ecosystem change and rankings of potential future conservation-compatible investment options, we carried out two socio-economic interviews. We interviewed 338 respondents comprising 227 male household heads and 111 women (either wives of male household heads or household heads themselves) from 250 households in July 2019 (129 respondents from 100 households) and July 2020 (209 respondents from 150 households). To account for potential gender effects, one third of the respondents was selected to be women and two-thirds to be men. The interviews were carried out by 10 trained, residents that were well known to, and trusted by, the community members, and all spoke Maa. The 338 respondents were distributed over the four zones such that 37 were from the Mara Reserve gates (mainly rangers and wardens), 129 from the conservancies zone, 87 from the Loita Plains and 85 from Siana. The enumerators administered a total of 443 questions in 2019 and 585 questions in 2020. The interview questions covered a wide range of themes but only a small sample is covered here for brevity. The themes included here are (1) household and respondent characteristics, (2) landowners' willingness to be part of a new conservancy, including by removing existing fences, (3) fences and their characteristics, (4) household conservation benefits, (5) household livelihood options, (6) community ranking of conservation-compatible (green) investment options and (7) Effects of Covid-19 pandemic on the households during March-July 2020. The Mara reserve rangers and wardens responded to some questions in their capacities as employees of the reserve and to others as local community members because the same set of questions were administered to all the respondents and some were not relevant to the reserve.

We conducted scenario analyses for potential restoration of the Mara-Loita wildlife migrations using known historical hotspots of wildlife species' abundance and richness and factoring in the major contemporary constraints to, and rough costs of, restoration efforts under each scenario.

Lastly, we reviewed peer-reviewed journal articles, books, and gray literature, including personal memoirs, government reports, project reports and other materials, to summarize key findings of recent studies and reconstruct a brief recent conservation history of the Mara. The specific literature reviewed focused on wildlife abundance and distribution and land use changes through the past century with emphasis on the changes occurring within the recent decades. The review also evaluated the changes in human and livestock population, settlements, rainfall and temperature patterns, land tenure, land fragmentation through fencing and socio-cultural and political practices. The review also considered patterns of legal and illegal exploitation of wildlife, wildlife policies, pieces of legislation, institutions, governance, and markets.

Relevant datasets were amalgamated and analyzed using various off-the-shelf software packages, such as ArcGIS Online, and bespoke scripts written in various programming languages.

4. RESULTS

4.1. Long term trends of the migratory Mara-Loita wildebeest, zebra, Thomson's gazelle and eland

Here, we show the massive and persistent decline in numbers of the common large wildlife species in the Mara using, as illustrative examples, the four species engaged in the Mara-Loita migration, namely wildebeest, zebra, Thomson's gazelle, and eland. Specifically, the number of the Mara-Loita wildebeest declined by 81% from about 123,000 in 1977 to under 24,000 in 2016 (Fig 10). Similarly, zebra numbers plummeted by 66% from nearly 63,000 in 1977 to below 22,000 in 2016 (Fig 12). Thomson's gazelle numbers decreased by 85% from almost 105,000 in 1977 to about 15,000 in 2018 (Fig 14). Lastly, eland reduced by 74% from almost 5,500 in 1977 to about 1,400 in 2018 (Fig 16). The Mara community has also noticed the declining trend in the Mara-Loita wildebeest, zebra, and Thomson's gazelle numbers during 2010-2020, most especially in their wet season range on the Loita Plains (Fig. 11). But they also provide some support for increase in numbers of the Mara-Loita wildebeest, zebra and Thomson's gazelle in the Mara Reserve and the conservancies, suggesting that some animals displaced from the Loita Plains have become sedentary in the protected parts of their dry season range (Figs 11,13,15).

The wildlife declines are persistent despite strong variability in local rainfall, with droughts punctuated by wet periods, establishment, and expansion of wildlife conservancies since 2005, or contrasting life-history traits (e.g., body size, gut morphology or digestive physiology (ruminant versus non-ruminant)) and strategies (e.g., feeding style (grazer, browser, mixed feeder), foraging style (resident, migratory or wide ranging) of the species. These considerations plus the fact that the wildlife losses are occurring throughout the entire GME implicate the role of a pervasive factor that adversely affects all the wildlife species. The trends demonstrate that the collapse of the Mara-Loita wildlife migration is the outcome of a process that has been going on for more than 41 years during which time high-quality monitoring data have been available. They also demonstrate that, at the ecosystem level, there is little evidence that the protected areas have slowed down the wildlife losses. This is not to say that conservancies have not provided homes for some wildlife species displaced from other parts of the ecosystem. The magnitude of the losses makes continued monitoring a top conservation priority to closely track current trends given the accelerating land use developments, including construction of fences in the Mara.

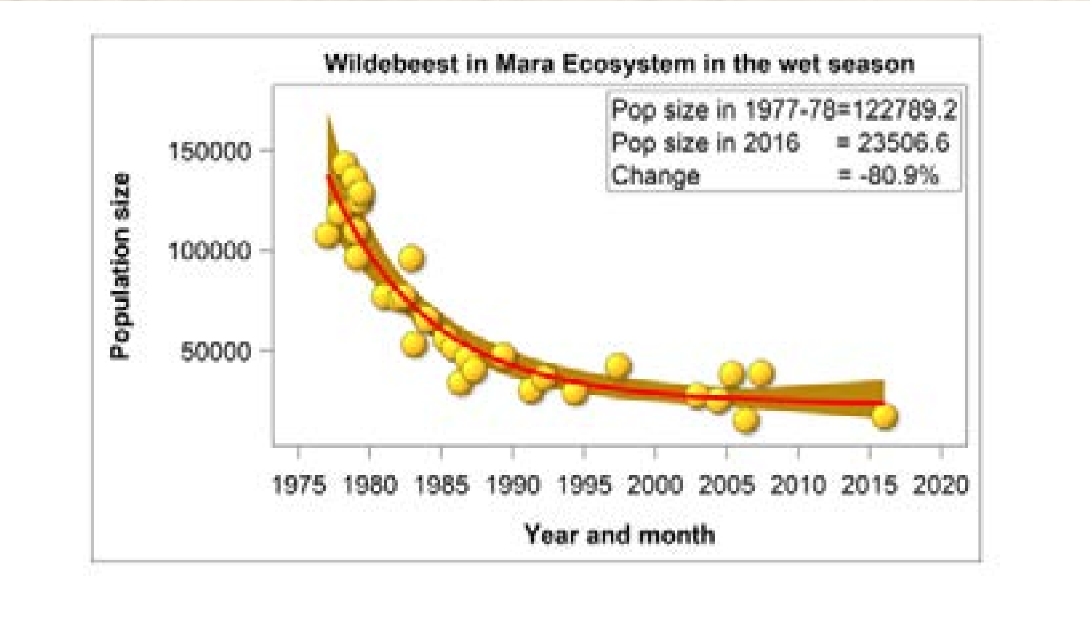

Fig 10. Population trend of the Mara-Loita wildebeest from 1977 to 2016.

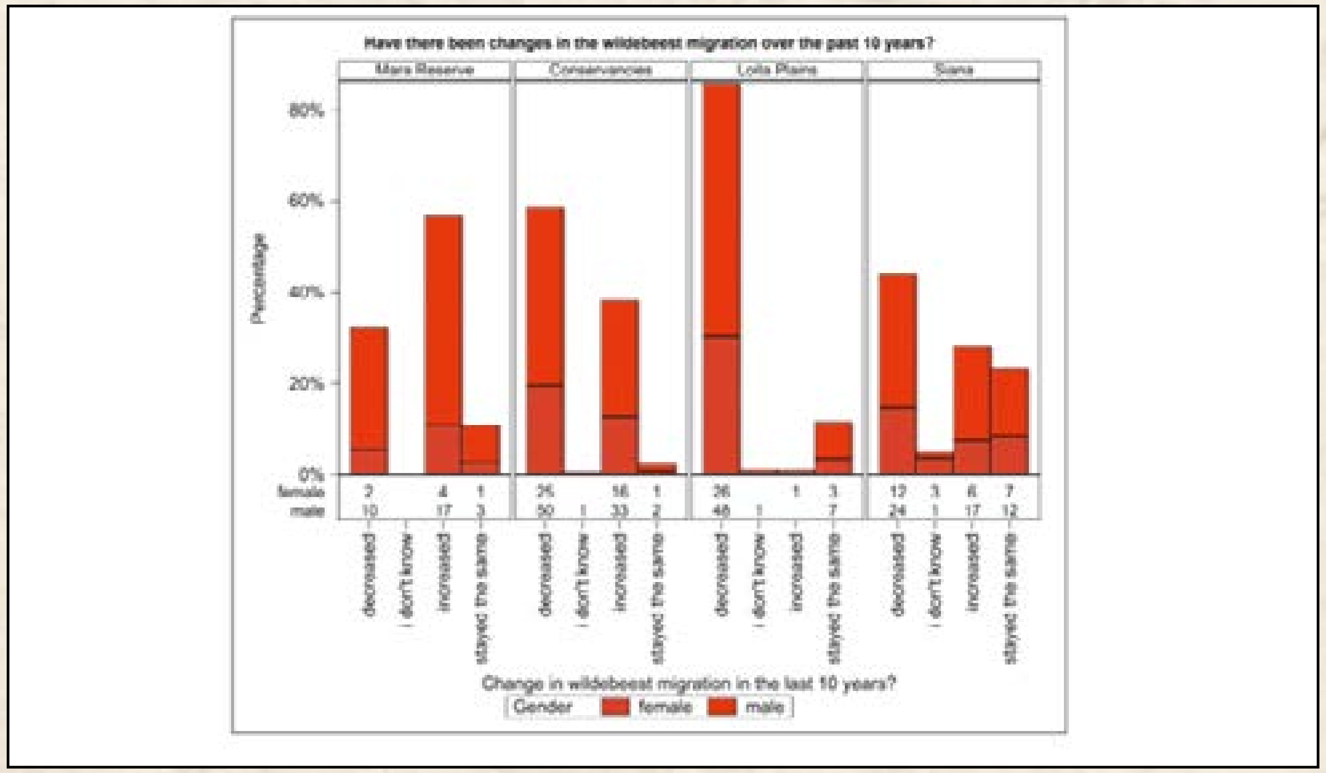

Fig 11. Mara community perception of population trend of the Mara-Loita wildebeest from 2010 to 2020.

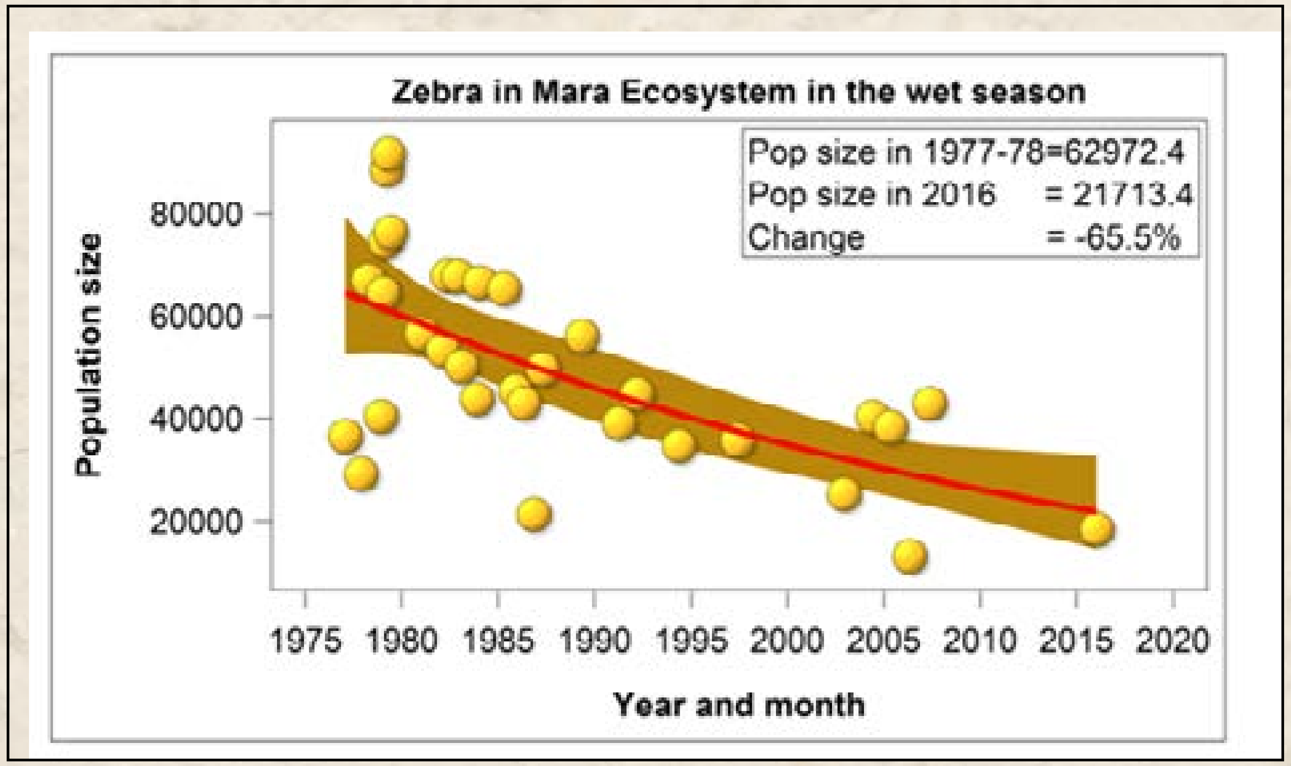

Fig 12. Population trend of the Mara-Loita zebra from 1977 to 2016.

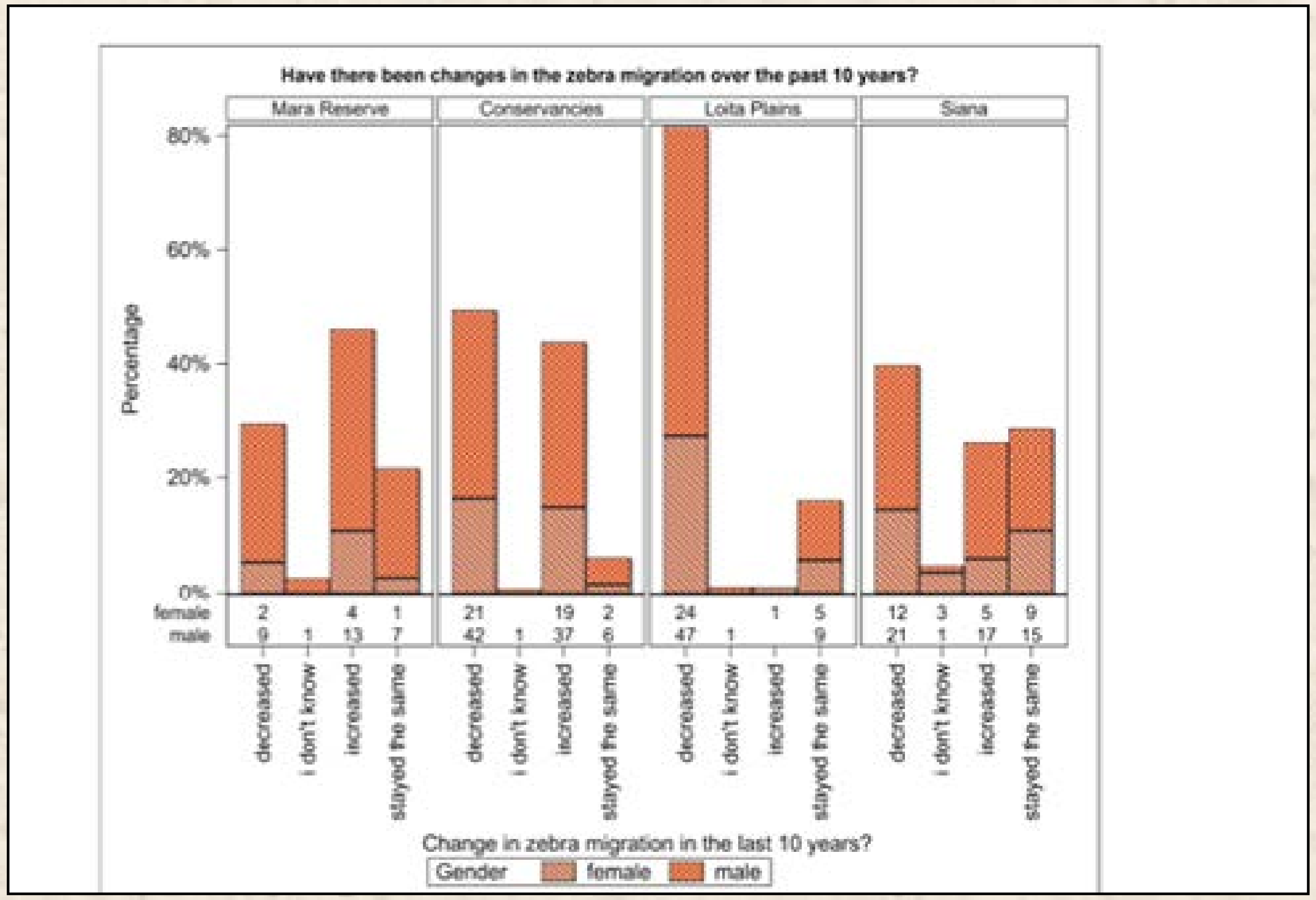

Fig 13. Mara community perception of population trend of the Mara-Loita zebra from 2010 to 2020.

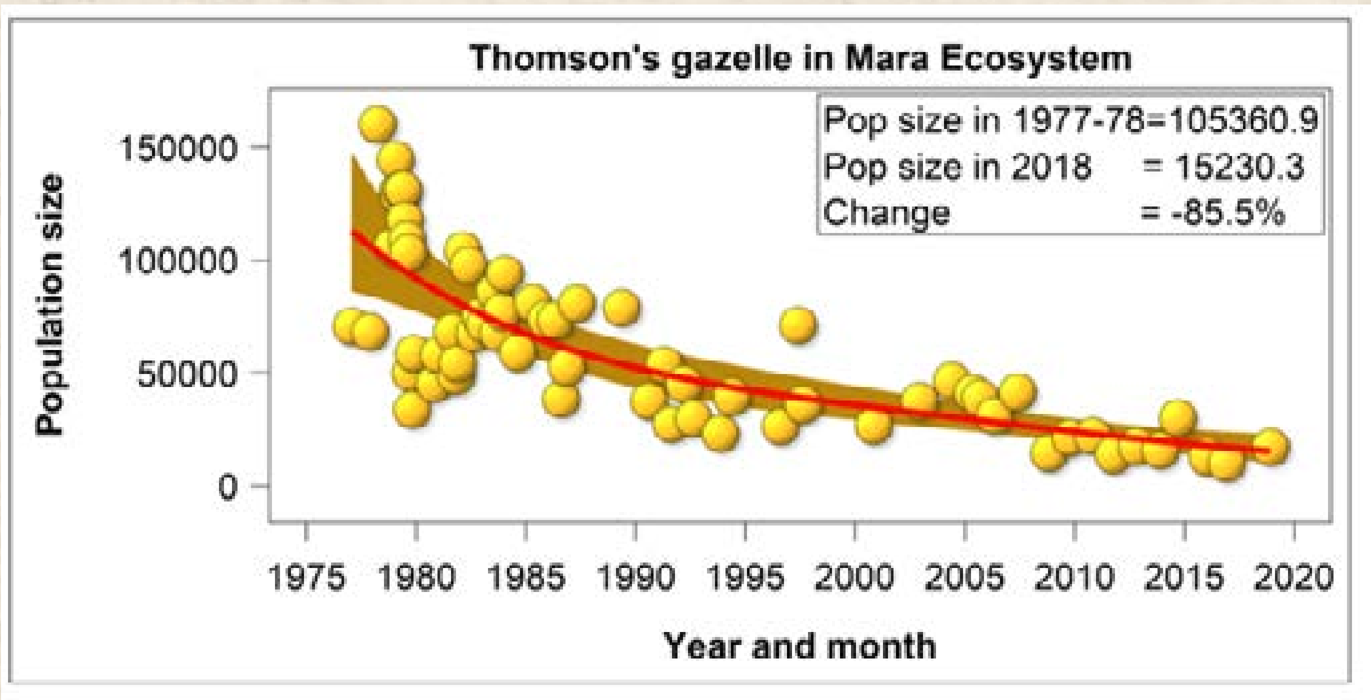

Fig 14. Population trend of the Mara-Loita Thomson's gazelle for both the wet and dry seasons from 1977 to 2018.

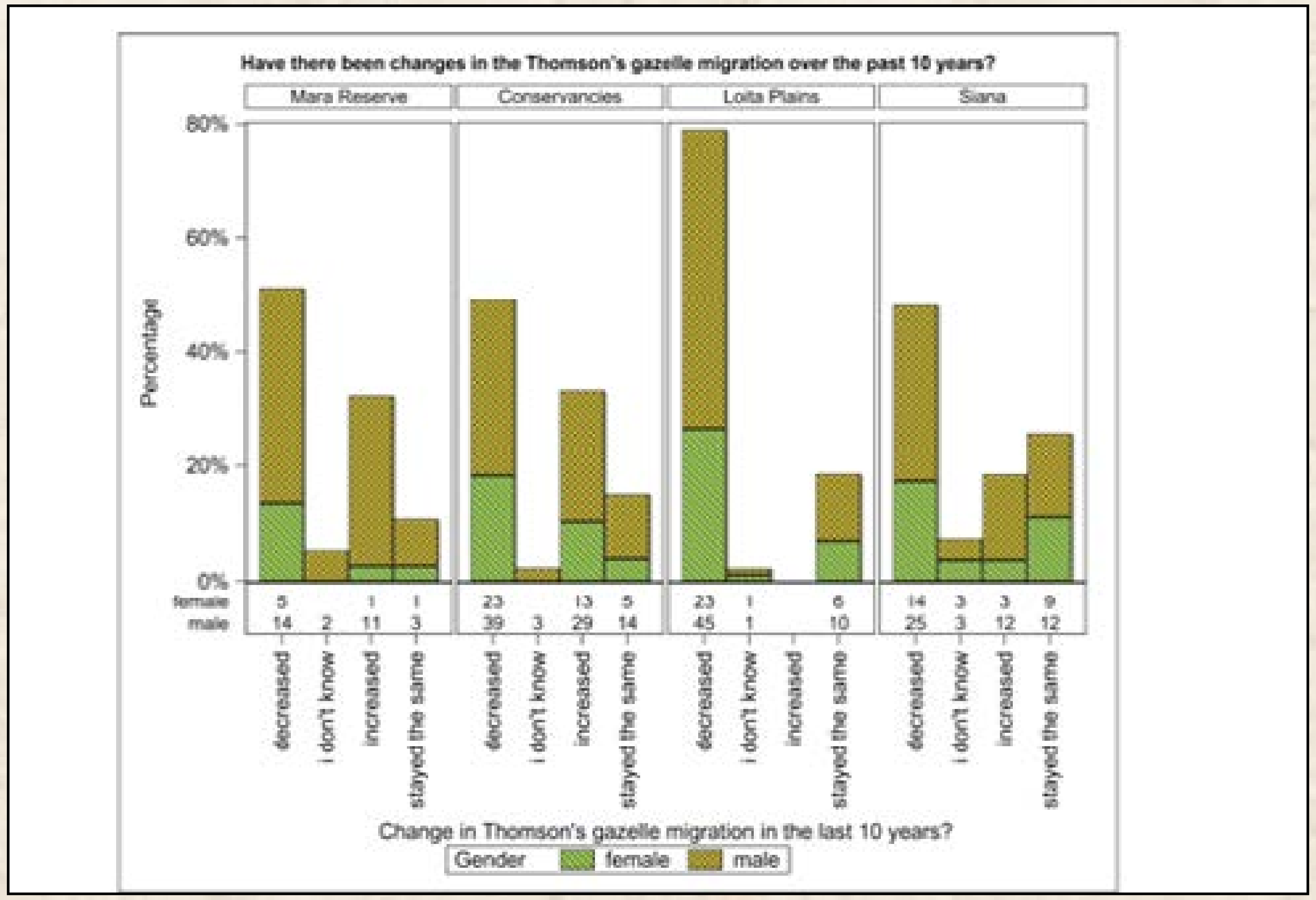

Fig 15. Mara community perception of the population trend of the Mara-Loita Thomson's gazelle from 2010 to 2020.

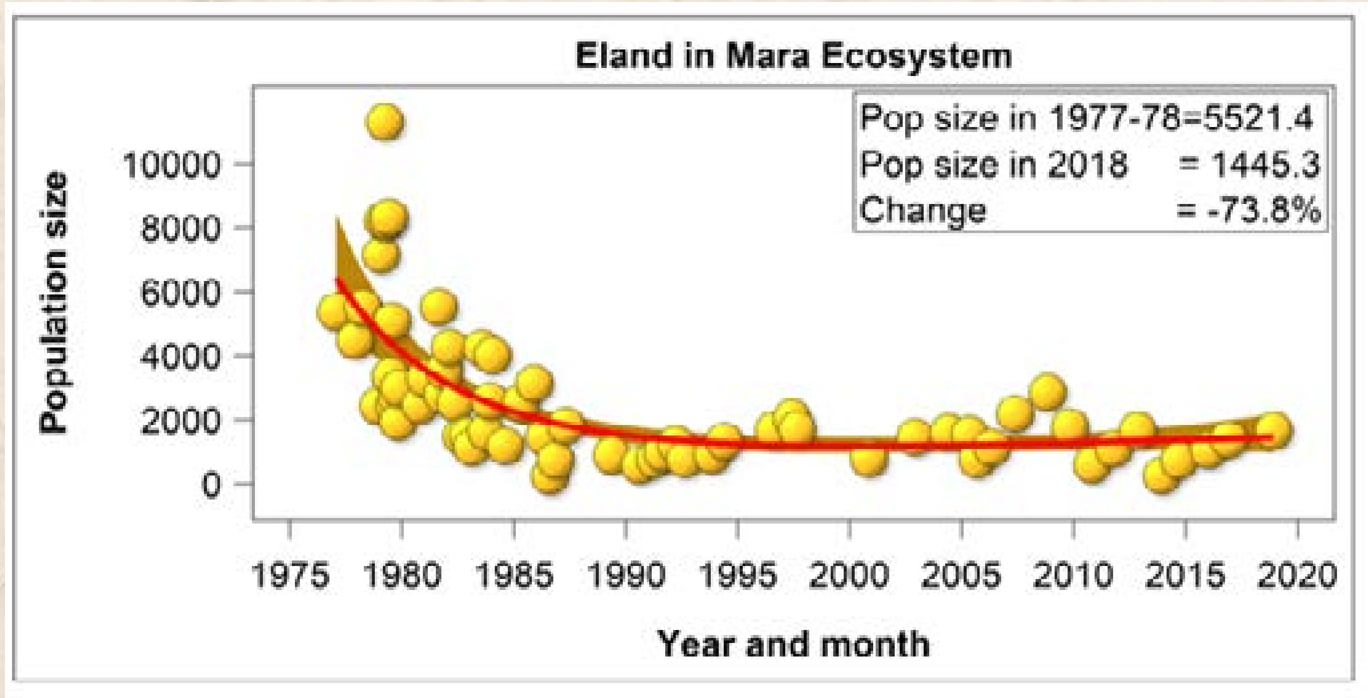

Fig 16. Population trend of the Mara-Loita eland for both the wet and dry seasons from 1977 to 2018.

4.2. Livestock population trends

In contrast to wildlife, livestock have been thriving in the same period that wildlife is being severely depleted in the Mara. Notably, cattle that require more mesic conditions, declined somewhat by 14% from 218,391 in 1977-1978 to 187,672 in 2018, notably during 2005-2010, a protracted dry period (Fig 17), but the numbers of sheep and goats have been increasing exponentially, rising by 306% from 165,735 in 1977 to 673,606 in 2018, with marked increase apparent from 1990 (Fig 18). The livestock trends rule out climate change as the main cause of the wildlife losses because climate would be expected to similarly affect co-occurring wildlife and livestock. This suggests that human activity, that promotes livestock at the expense of wildlife, is the leading proximate cause of the wildlife losses in the Mara.

Despite the slight drop in cattle numbers and exponential increase in the numbers of sheep and goats, the interviewed Mara residents reported a decline in cattle, sheep, and goat numbers at the household level. This perception is consistent with a steep decline in cattle numbers per capita in the Mara from 6.0 (210,586 cattle/34,851 people) in 1979 to 1.5 (223,067 cattle/147,702 people) in 2019. The number of sheep and goats per capita also marginally declined from 4.6 (160,772 sheep and goats /34,851 people) in 1979 to 4.4 (635,393 sheep and goats / 147,702 people) in 2019. Thus, the Mara pastoralists were far more cattle poorer in 2019 than in 1979. To maintain the same level of cattle wealth and lifestyle as they had in 1979, they would need a total of 886,212 (=6.0 cattle per capita x 147,702 people) cattle, or 675,626 (=886,212-210,586 cattle) more cattle than they had in 2019. This explains the seeming paradox of the Mara residents' perception of a decline in sheep and goat numbers at the household level despite the exponential increase in their numbers at the ecosystem level.

The Mara residents would have to maintain a faster than exponential growth in cattle, sheep and goat numbers to maintain their livestock wealth and lifestyle. This is impossible given finite land and other resources and expansion of conservancies. It follows logically that socio-economic investments that support human livelihoods must accompany expansion of conservancies to avoid driving poor pastoralists into poverty traps in the long-term. Such investments are necessary even without expansion of conservancies because the current human population size in the Mara is already too high relative to per capita livestock holdings to derive decent livelihood from livestock herding alone.

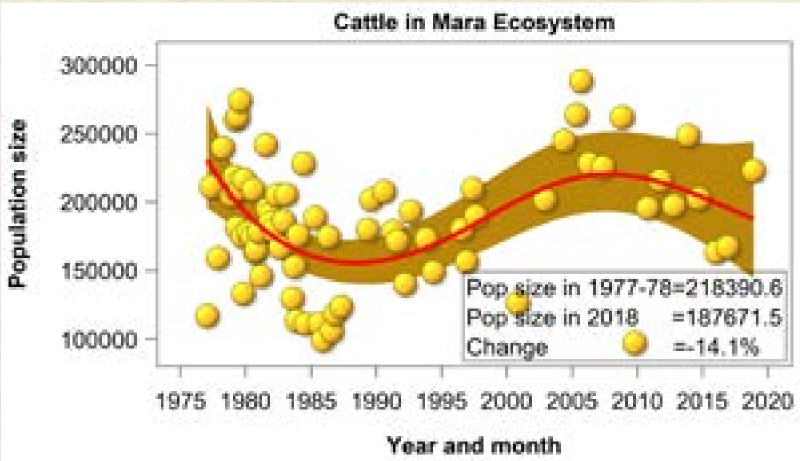

Fig 17. Cattle in the Mara Ecosystem

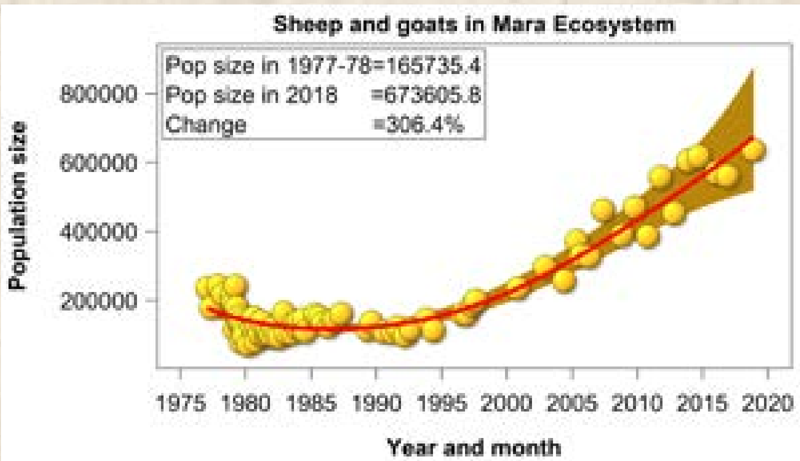

Fig 18. Sheep and goats in the Mara Ecosystem

4.3. What areas in the Mara were historically preferred by the Mara-Loita migrants (migrant hotspots)?

Here we describe abundance hotspots for the four migratory Mara-Loita wildlife species in the wet and dry seasons when the DRSRS aerial monitoring surveys began in 1977-1979 and recently (2015-2018). The abundance hotspots during 1977-1979 provide quantitative evidence of the places wildlife preferred in the wet and dry seasons. They thus identify priority areas in the landscape where new wildlife conservancies should preferentially be located. Based on this criterion, the Loita Plains emerge as the highest priority area for establishing new conservancies if the Mara-Loita migration is to be saved from the threat of imminent extinction. The hotspots demonstrate ecosystem-wide extermination of wildlife from their former preferred ranges, most remarkably from their wet season feeding and calving range on the Loita Plains, precipitaing the collapse of the Mara-Loita migration.

In the wet season during 1977-1979, the four migrant species concentrated mainly on the Loita Plains, particularly south of the Ngorengore shopping center, and extended eastwards to near the Ewaso Ng'iro shopping center, southwards to Maji Moto and to its north east. Their distribution also extended westwards to the plains located to the southeast of Lemek and east of Aitong shopping centers (Fig 19). Additional abundance hotpots were in Siana, near Naikara shopping center, and in the south eastern parts of Siana near the Kenya-Tanzania border (Fig 19). Some hotspots were in the Conservancies zone near Aitong shopping center and south west of Aitong towards the Mara Reserve and north east of Mara Rianta, adjacent to the Mara River (Fig 19). In the Mara Reserve, a hotspot was found in the Mara Triangle along the Kenya-Tanzania border (Fig 19). The wet season hotspots observed in 1977-1979 had, quite unfortunately, all disappeared by 2015-2018 (Fig 19). This demonstrates ecosystem-wide decimation of the Mara-Loita migratory species, with evident spill-over effects on the nominally protected Mara Reserve.

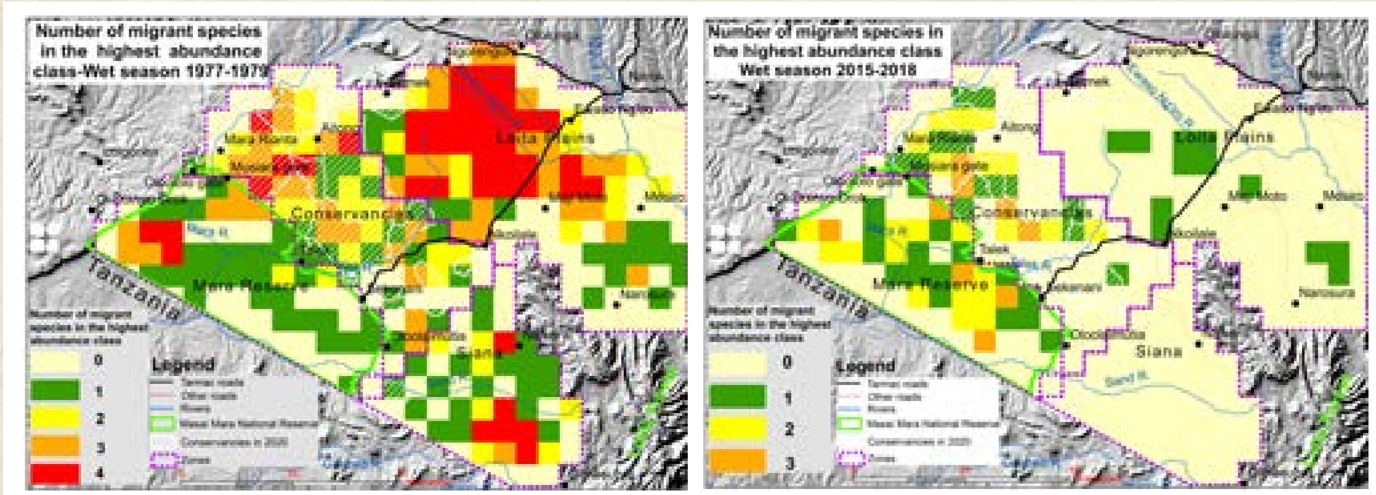

Fig 19: The number of species of the Mara-Loita migratory wildlife in the highest abundance class in the wet season during 1977-1979 and 2015-2018. The maximum number of the Mara-Loita migratory species is four (wildebeest, zebra, Thomson's gazelle, and eland).

In the dry season, during 1977-1979, an abundance hotspot was located near Narosura and in Siana near the Kenya-Tanzania border, close to the Grumeti River (Fig 20). In the conservancies zone, the wet season hotspot found near the Mara River to the north west of Mara Rianta shopping center was also apparent in the dry season (Fig 20). Similarly, part of the hotspot observed in the wet season to the south west of Aitong, towards the Mara Reserve, was also maintained through the dry season (Fig 20). A hotspot was also located near the Talek river to the east of Talek shopping center. The Mara-Loita migrants also congregated in the Mara Reserve in an area south of Talek shopping center in the dry season (Fig 20) and near the confluence of the Talek and Mara rivers. A further hotspot was evident to the east of the Mara river, west of Talek shopping center and running southwards to the Kenya-Tanzania border. In the dry season, during 2010-2014, no more hotspot was left in the Loita Plains (Fig 20). But a hotspot was apparent in the Conservancies zone, near the Mara River and north east of Mara Rianta (Fig 20). In the Mara Reserve, hotspots were evident to the north west of the Mara Triangle and south of Talek shopping center (Fig 20).

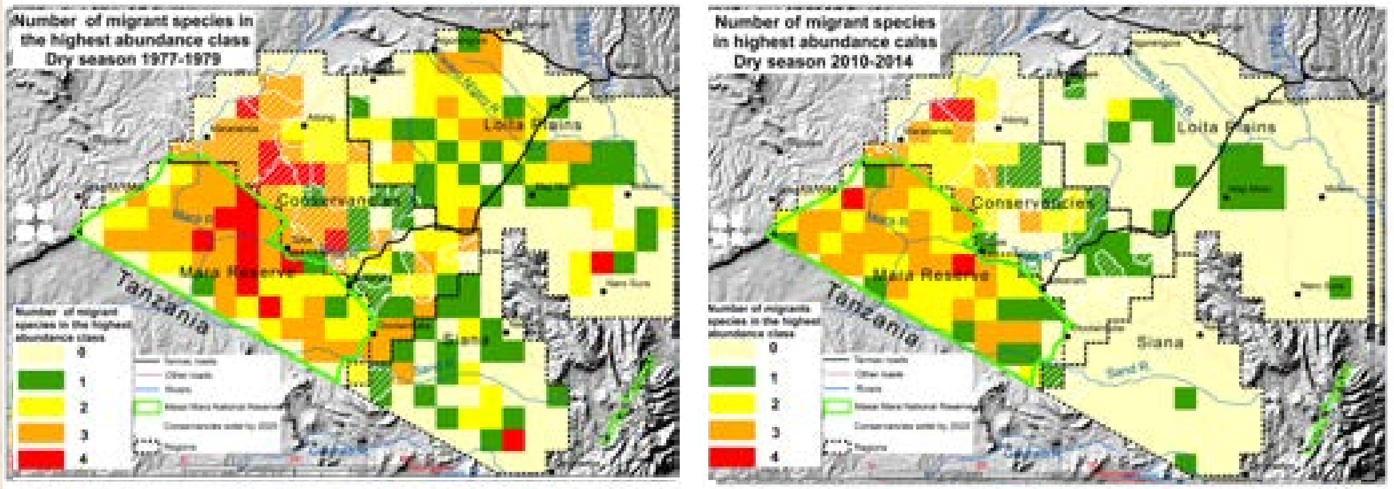

Fig 20: The number of the Mara-Loita migratory species in the highest abundance class in the dry season during 1977-1979 and 2010-2014. The maximum number of the Mara-Loita migratory species is four (wildebeest, zebra, Thomson's gazelle, and eland).

4.4. Hotspots of the Mara-Loita migrants in relation to the distributions of fences, sheep and goats

Based on the DRSRS aerial survey data for 1977-1979, the Mara-Loita migrants were abundant over almost one third of the entire Loita Plains in the wet season (Fig 19). But the migrants have since been decimated or displaced from the Loita Plains by a combination of rising human population size, settlements, agriculture, fences, and other pressures from within and outside the Loita Plains. Privatization of land ownership from communal tenure through group ranches to individual parcels, followed by enclosure in fences, has struck the most telling blows on the migrant wildlife in recent times. Notably, by 2020 fences had covered more than half of the Loita Plains and most of the former wet season hotspots of migrant wildlife (Fig 21). It is thus fair to say that the spread of fences, like wildlife, in the Loita Plains from 2015 to 2020 is the primary proximate cause of the final collapse of the Mara-Loita migration. Fences continue to proliferate and become denser from the Ngorengore shopping center through the Mara-Loita migrants' prime calving areas and spread to the south east past Maji Moto (Fig 19). Fencing has had a far more devastating impact on the hotspots of the Mara-Loita migrants on the Loita Plains, their prime wet season range, than on their hotspots in either the Siana or the Conservancies zone (Fig 19). This is evident from the DRSRS data for 2010-2014 which demonstrates that all the former hotspots in the Loita Plains are no more (Fig 19).

Moreover, sheep and goats are increasing exponentially and now densely occupy over 95% of all the community areas in the Mara (Loita Plains, Conservancies and Siana, Fig 23). They compete with wildlife for food, water and space and potentially amplify the strong decline of migrant wildlife, also within the protected areas.

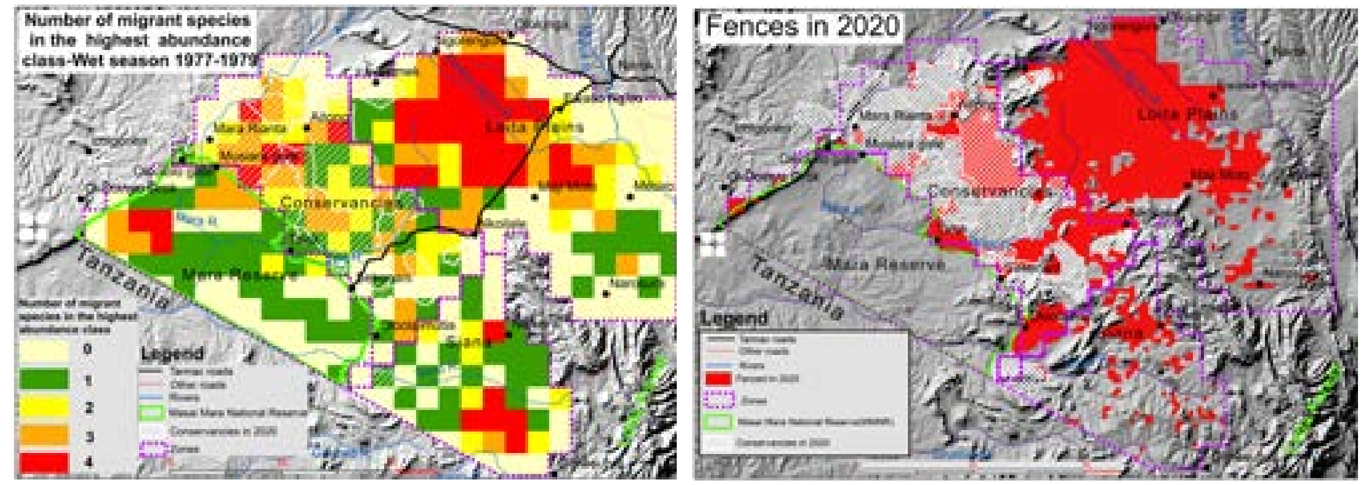

Fig 21. The number of the Mara-Loita migratory species in the highest abundance class in the wet season in the 1970s (1977-1979) and, the distribution of fences in 2020. The maximum number of the Mara-Loita migratory species is four (wildebeest, zebra, Thomson's gazelle, and eland).

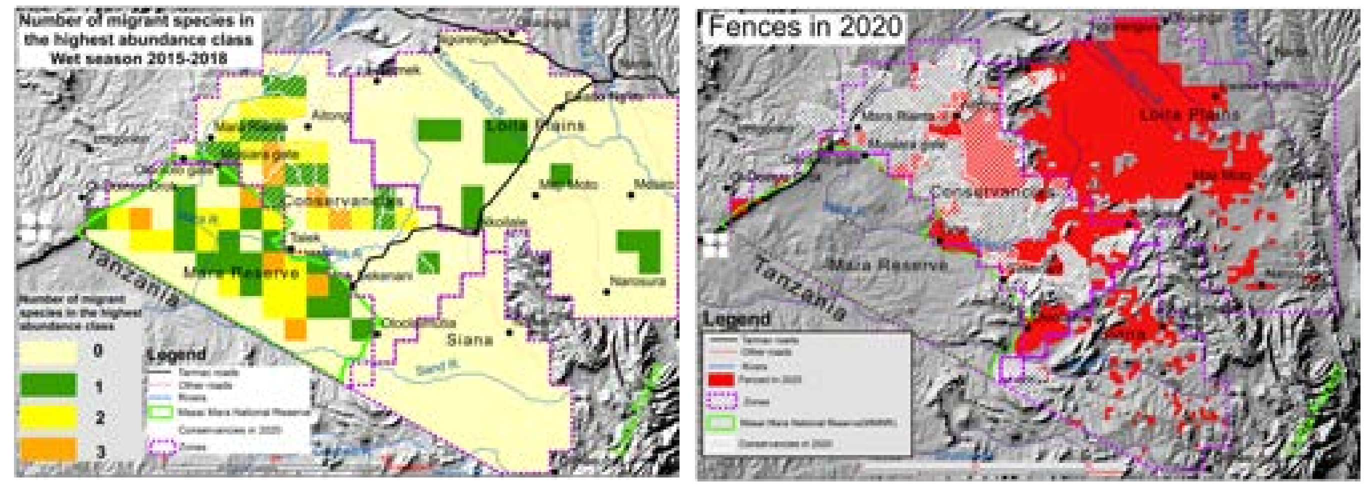

Fig 22. The number of the Mara-Loita migratory species in the highest abundance class in the wet season during 2015-2018 and the distribution of fences in 2020. The maximum number of the Mara-Loita migratory species is four (wildebeest, zebra, Thomson's gazelle, and eland).

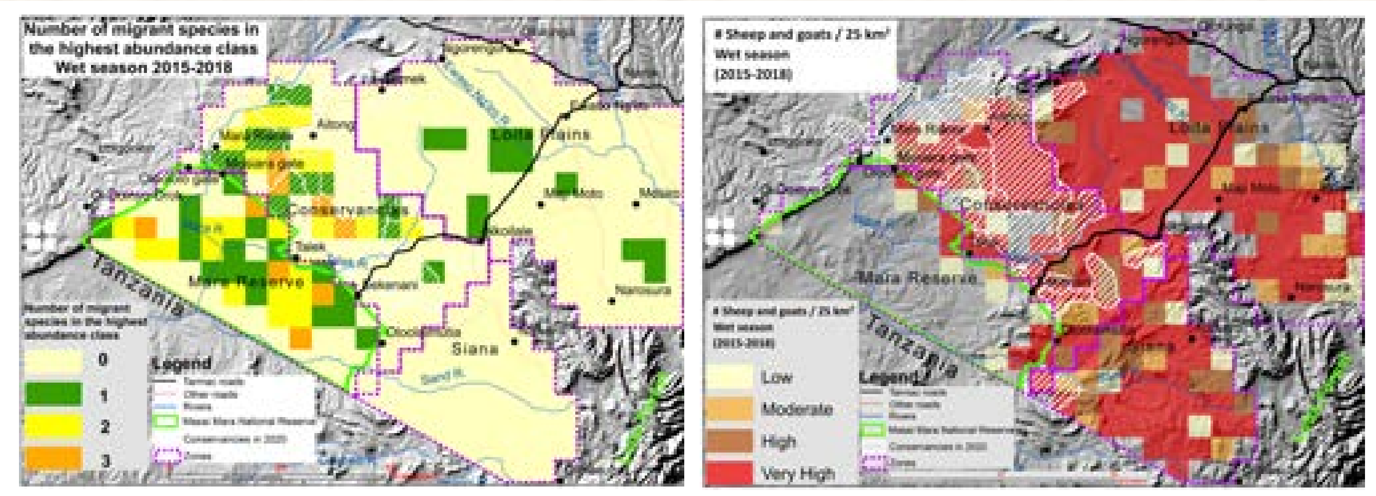

Fig 23. The number of the Mara-Loita migratory species in the highest abundance class in the wet season during 2015-2018. The maximum number of the Mara-Loita migratory species is four (wildebeest, zebra, Thomson's gazelle, and eland). The density of sheep and goats is grouped into low to very high classes, corresponding to the 25th, 50th, 75th and 95th percentiles of their frequency distribution from 1977 to 2018.

4.5. Hotspots of the Mara-Loita migrants in relation to human population density

Human population density is increasing in the Loita Plains and is currently high, mainly around Ngorengore shopping center and spreading southwards. Also, human population density is relatively high around Ewaso Ng'iro shopping center and north of Narosura shopping center (Fig 24). The hotspots of the Mara-Loita migrants during 1977-1979 were covered by high to low human population density based on the Kenya National Bureau of Statistics (KNBS) data disaggregated to 5 x 5 km scale (Fig 24). When the hotspots of the Mara-Loita migrants in the wet season, during 2015-2018, are compared with the distribution of the human population density in 2019, it is apparent that areas with even relatively low human population density have lost their migratory species (Fig 25), implying that human population increase is not the only major driver of the recent collapse of migratory wildlife on the Loita Plains. The areas of low human population density are typically enclosed in large fences that exclude wildlife.

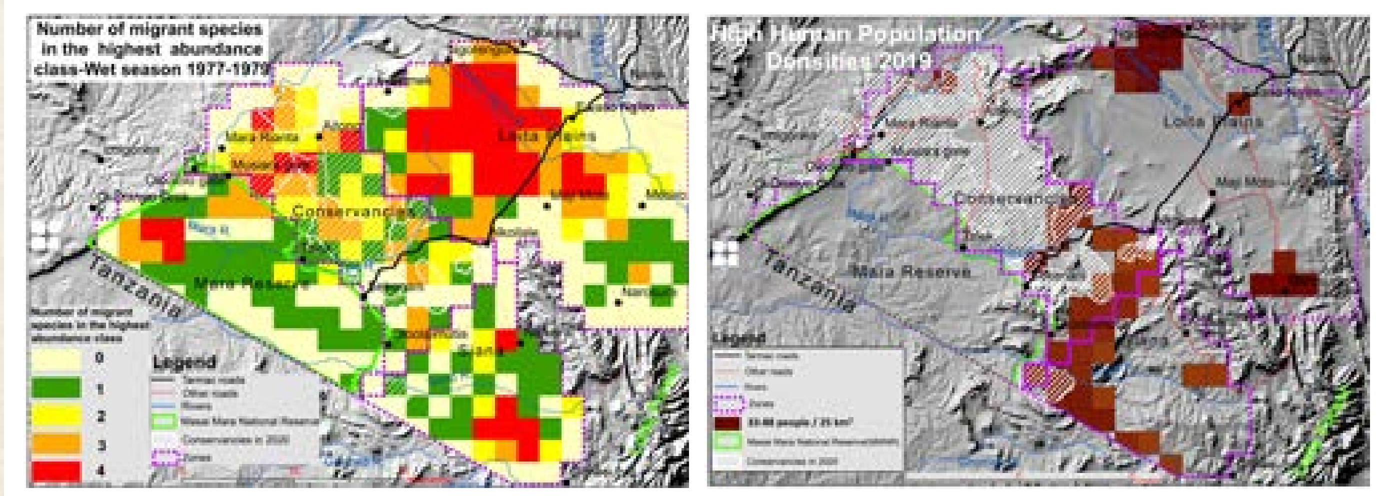

Fig 24 Hotspots of the migrant herbivores in the wet season in the late 1970's in relation to the areas of high human population density in 2019.

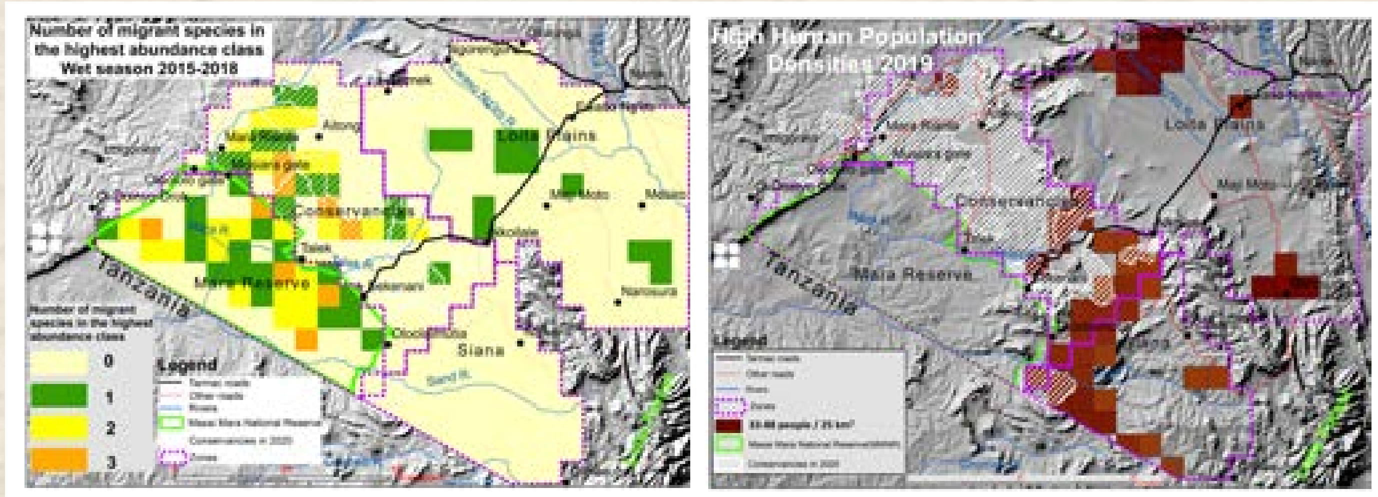

Fig 25 Hotspots of the migrant herbivores in the wet season in the late 2010's in relation to the areas of high human population density in 2019.

4.6. What areas in the Mara were historically preferred by resident wildlife species (resident hotspots)?

Unlike migrant wildlife, the resident wildlife species showed little preference for the Loita-Plains in the wet season and mostly stayed in the Mara Reserve and the areas directly north of it (conservancies at present) (Fig 26). So, during the 1977-1979 wet seasons, hotspots of the resident wildlife were located mainly in both the Mara Reserve and the adjoining area now covered by conservancies (Fig 26). During 2015-2018 resident wildlife had generally declined in all the four study zones regardless of their nominal protection level (Fig 26). Generally, the same patterns evident in the wet season characterized the dry season (Fig 27). Combined with the overall trends of the migrants (Figs 10,12,14,16), this shows that the decline of these species was effectively spatially uniform - it happened everywhere. This may imply that the current protected areas are too small to retain even their current levels of biodiversity in the wake of the mounting anthropogenic pressures impinging on their borders.

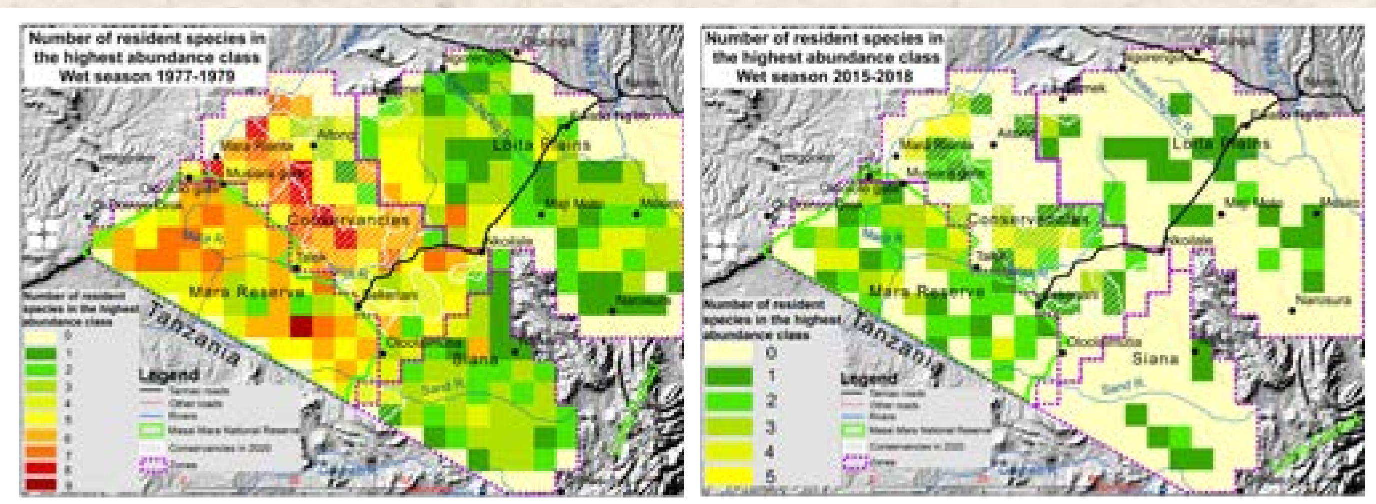

Fig 26. The number of the resident species in the highest abundance class in the wet season during 1977-1979 and 2010-2014. The maximum number of the resident species is nine (buffalo, giraffe, Grant's gazelle, coke's hartebeest, topi, impala, ostrich, waterbuck, and warthog).

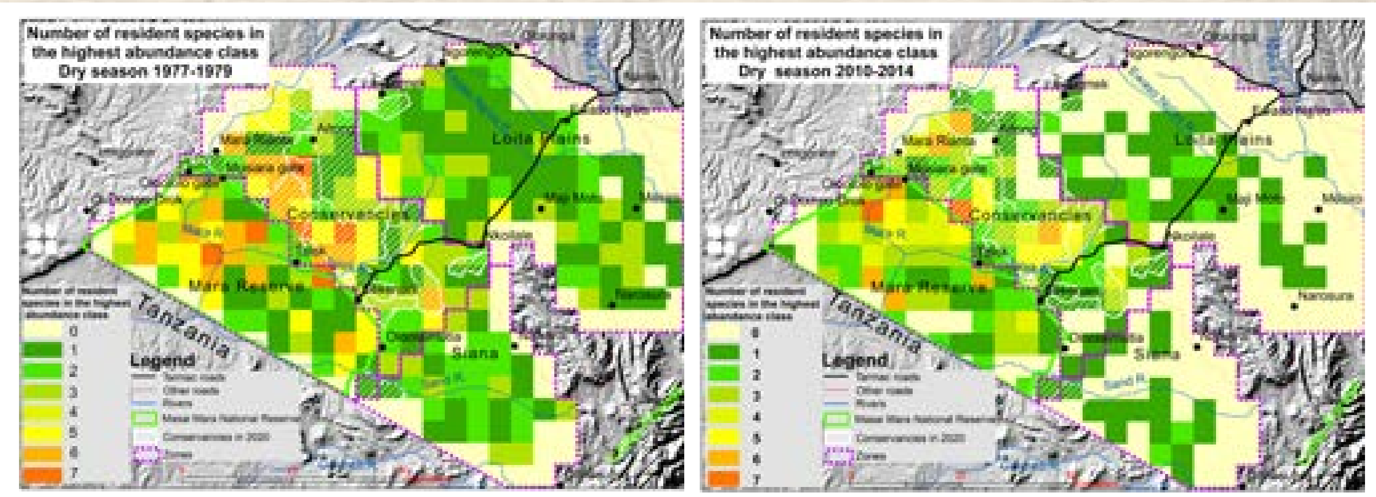

Fig 27. The number of the resident species in the highest abundance class in the dry season during 1977-1979 and 2015-2018. The maximum number of the resident species is nine (buffalo, giraffe, Grant's gazelle, coke's hartebeest, topi, impala, ostrich, waterbuck and warthog).

4.7. What areas in the Mara were historically preferred by livestock (livestock hotspots)?

The density of sheep and goats in the dry season during 1977-1979 was generally low, with scattered density hotspots evident, especially near Ngorengore, Ewaso Ng'iro and Maji Moto shopping centers, and stretching north westwards, around Narosura and to its north east, and south of Lemek shopping center (Fig 28). In the conservancies zone, high sheep and goat densities were apparent around Aitong and Talek, to the north east of Talek, along the boundary of the Mara Reserve and the Conservancies zone (Fig 28). Sheep and goats were also common to the south east of Siana, towards the Kenya-Tanzania border and the Loita forest (Fig 28). By contrast, during 2010-2014, sheep and goats had spread out to densely cover almost all the Mara, but most especially the Loita Plains, Conservancies zone and Siana, with a few patches of low to moderate density still apparent in the conservancies zone to the north west of Talek and west of the Narok-Sekenani tarmac road (Fig 28). In the Loita Plains, the low to moderate density patches are apparent in areas to the north west of Maji Moto, south east of Maji Moto and stretching eastwards towards the Rift Wall (Fig 28). Also, low to moderate density areas are evident around the more arid Narosura area and stretch to the west, north of Mosiro shopping center and east of the Ewaso Ng'iro shopping center (Fig 28). In Siana, low to medium density areas are found near the Sand River, stretching towards the Rift Wall and the Kenya-Tanzania border (Fig 28).
In the Mara Reserve, sheep and goats were concentrated at high densities near the border with Siana, especially around the Oloolaimutia shopping center and the Siana conservancies (Fig 28). Similarly, high sheep and goat densities characterize the boundary of the Mara Reserve and Sekenani shopping center and inside the Mara Reserve near the Talek shopping center.
Low to moderate sheep and goat densities were located inside the Mara Reserve to the immediate west of Oloolaimutia shopping center, south of the Talek shopping center, north west of the Talek shopping center and around the Mara River in the Mara Triangle (Fig 28).
Sheep and goat density hotspots were very similar in the wet and dry seasons, but the spatial extents of the hotspots were larger in the dry season during 1977-1979 (Fig 29).
Sheep and goats were densely concentrated on the Loita Plains from Ngorengore shopping center southwards, on both sides of the Ewaso Ng'iro River, eastwards to Ewaso Ng'iro shopping center and south westwards along the Narok-Sekenani tarmac road (Fig 29). From Ewaso Ng'iro River, sheep and goats occurred at high densities south westwards towards the source of the Talek River and along the border of the conservancies zone and the Loita Plains from the Narok-Sekenani tarmac road in the north west and then to the east, astride the Talek River (Fig 29). Sheep and goats also occur at high densities around Narosura and extend northwards to Mosiro shopping center (Fig 29). In Siana, sheep and goats are abundant near Naikara and southwards towards the Kenya-Tanzania border and eastwards to the Loita forest (Fig 29). In the Mara Reserve, sheep and goat hotspots are rare except near the Oloolaimutia shopping center (Fig 29). In the conservancies zone, sheep and goats are densely distributed around the Oloolaimutia shopping center, eastwards towards the border of Siana conservancies and southwards towards the Kenya-Tanzania border (Fig 29).
Low to moderate sheep and goat densities were apparent in the Loita Plains in Maji Moto, east of Mosiro shopping center and west of Narosura shopping center (Fig 29). Similar sheep and goat densities were also found around Lemek shopping center and stretched south westwards towards the border of the conservancies zone, eastwards across the Talek River, north west towards the eastern and southern sides of Aitong and towards the Sekenani shopping center (Fig 29). Still, within the Conservancies zone, sheep and goats occurred at low to moderate densities around

Mara Rianta, north west of Talek shopping center, along the Mara Reserve boundary, from Sekenani shopping center northwards and then south eastwards towards the border with Siana (Fig 29). The concentration of this density class was notable to the north east of Siana and around Naikara but also to the south east of Siana, towards the Loita forest (Fig 29). In the wet season during 2015-2018, sheep and goat density hotspots were common throughout the entire Mara ecosystem except in the Mara Reserve (Fig 29) where a few scattered density hotspots were apparent to the south west of Oloolaimutia, west and north west of Talek (Fig 29). The low-moderate density classes were sparsely distributed across the entire Mara ecosystem. In the Loita Plains, a few hotspot patches stretched from the Ewaso Ng'iro River, southwards towards the border of Siana to the north of Maji Moto and South of Ewaso Ng'iro shopping center (Fig 29). A large area of low-moderate density was evident north and south east of Mosiro town, with a small patch apparent to the east of Narosura (Fig 29). In Siana, low-moderate density patches were visible in the south west and to the north of Naikara town (Fig 29). in the Conservancies zone, low-moderate density patches occurred to the north east of Sekenani shopping center, north west of Talek shopping center, east of Mara Rianta and north west of Aitong shopping center (Fig 29). Some patches in this density class occurred inside the Mara Reserve, north west of Oloolaimutia, around Talek, north west but east of the Mara River (Fig 29). Another patch in the same density class occurred at the Kenya-Tanzania border, south west of Oloolaimutia and near the Kenya-Tanzania border in the southwest corner of the Mara Triangle (Fig 29).

Cattle density hotspots in the wet season during 1977-1979 were common in Siana and the Conservancies zone and to the south east of the Loita Plains, between Narosura and Mosiro (Fig 30). A small cattle density hotspot was noticeable inside the Mara Reserve to the northwest of Talek town (Fig 30). A few cattle hotspots were in the Loita Plains near Ewaso Ng'iro shopping center, to the south west along the Narok-Sekenani tarmac road, to the north west of Ewaso Ng'iro shopping center, east of Ngorengore shopping centre and towards the Narok-Bomet tamac road (Fig 30). Low-moderate cattle densities were found in the Loita Plains, east of Ewaso Ng'iro shopping center, stretching south westwards along the Narok-Sekenani road, south eastwards towards Maji Moto shopping center and north westwards towards and past Mosiro shopping center (Fig 30). More low-moderate cattle density patches were observed east of Maji Moto, north westwards across the Talek River, south of Ngorongore to the source of the Talek River and between the source of the Talek River and Ewaso Ng'iro River (Fig 30). In the conservancies zone, patches of low-moderate livestock densities occurred to the east and north of the Sekenani shopping center, north west of Talek, near Mara Rianta, south east and north west of Aitong (Fig 30). In the Mara Reserve, low-moderate cattle density was observed south of Sekenani and another to the north west of Talek (Fig 30). In the wet season during 2015-2018, cattle density hotspots were fewer than during 1977-1979 and did not cover the entire ecosystem. Moreover, most of the cattle density hotspots were small in size except for those stretching from the north, next to the Narok-Bomet road, south westwards, past Ngorengore shopping center up to the vicinity of the Lemek shopping center, and eastwards past Ewaso Ng'iro shopping center (Fig 30). The other areas with low-moderate cattle concentrations were the following: south of Lemek town, along the boundary of the conservancies zone and the Loita Plains and then to the north east across the Talek River, East of Maji Moto town, west of Ewaso Ng'iro town, and north west and north east of Narosura (Fig 30). In the conservancies zone, patches of low-moderate cattle density occurred north of Talek town, north west and north east of Sekenani town, north east of Oloolaimutia along the boundary of Siana and the Conservancies zone, south of Mara Rianta, south and east of Aitong town (Fig 30). In Siana, low-moderate cattle densities were located along the boundary of Siana and the Conservancies zone and to the south east of Siana near the Kenya-Tanzania border (Fig 30). In the Mara Reserve, very high cattle densities were found east of Oloolaimutia and southwards up to the Sand River, near the Kenya-Tanzania border and to the east of Talek town (Fig 30). Low-moderate cattle densities were more prominent on the Loita Plains and in Siana than in the Conservancies zone or the Mara Reserve and covered a large area to the south east of the Narok-Sekenani tarmac road and a small portion of the same road stretch to the north west (Fig 30). Low-moderate cattle densities also covered most of the area to the north west of the Conservancy zone near the source of the Talek River, the conservancies zone to the south east and adjacent to Siana and to the north west of Talek town to the boundary of the Loita Plains (Fig 30). Other areas in the Conservancies zone with low-moderate cattle densities occurred to the north of Aitong and east of Mara Rianta town (Fig 30). Inside the Mara Reserve 5 patches were observed in the following areas: the Mara Triangle at the left lower corner next to the Transmara district, one in the Mara Triangle next to the Mara River and close to the Kenya-Tanzania border, one to the east of Talek town, 3 to the east and north west of Sekenani town and one to the south east of Mara Rianta (Fig 30).

In the dry season during 1977-1979, cattle density hotspots were found over the Conservancies zone, Siana and south east of the Loita Plains (Fig 31). The only other area with dense cattle concentration was located to the south of Mara Rianta and along the boundary of the Conservercies zone and the Loita Plains (Fig 31). Other areas of high cattle densities in the conservancies zone were the source of the Talek River and the areas to the east, south and north west of Maji Moto, near Ngorengore town, east and west of Ewaso Ng'iro town (Fig 31). In the Conservancies zone, cattle densities were notably high in the following areas: At and around Aitong shopping centre, stretching south eastwards along the boundary of the conservancies zone and the Loita Plains and to the boundary of Siana (Fig 31). Other areas with small pockets of high cattle densities were the following: East and south east of the Talek town, north eastwards towards the boundary of the Conservancies zone and the Loita Plains (Fig 31), north west of Talek town and east of Mara Rianta shopping centre. In Siana, cattle were densely distributed to the south west towards the Kenya-Tanzania border (Fig 31). In the Mara Reserve, cattle occurred in high density in only a small area to the north west of Talek town (Fig 31). Cattle occurred at low-moderate densities more commonly in the Loita Plains than in any of the other three zones (Fig 31). Most of the cattle occurring at low-moderate densities in the Loita Plains were mostly found near the source of the Talek River and north eastwards to the Ewaso Ng'iro River and south eastwards up to the Narok-Sekenani tarmac road (Fig 30). Cattle also occurred at low-moderate densities at Maji Moto town and to the east of the town, at Ewaso Ng'iro town and south westwards, north and south of Mosiro and north of Narosura town (Fig 31).

In the dry season during 2010-2014 cattle occurred at higher densities in the Loita Plains, Siana and the Mara Reserve than in the conservancies zone (Fig 31). In the Conservancies zone, cattle densities were high from the Narok-Bomet road, south eastwards, across the Ewaso Ng'iro River to the Narok-Sekenani tarmac road (Fig 31). Cattle were also densely distributed from Ewaso Ng'iro River westwards to Lemek, southwards along the border of the conservancies zone and the Loita Plains and then eastwards across the Talek River (Fig 31). In the conservancies zone, cattle were concentrated in an area-oriented eastward of Sekenani town to the boundary of Siana and the conservancies zone and south westwards towards Oloolaimutia town (Fig 31). Other notable areas of cattle concentration were from Talek town to the north west and south of Mara Rianta town (Fig 31). Additional three areas of cattle concentration occurred to the north, east and south east of Aitong (Fig 31). In Siana, cattle congregated on the eastern side to Naikara town, to the south east towards the Loita forest and to the south west next to the Kenya-Tanzania border (Fig 31). Inside

the Mara Reserve, cattle were concentrated to the west of Oloolaimutia, north westwards past the Sekenani shopping center and from Oloolaimutia south westwards along the Sand River near the Kenya-Tanzania border (Fig 31). Inside the Reserve, high cattle densities occurred to the east of Talek town and south east of Mara Rianta town (Fig 31).
Low-moderate cattle density was more common on the Loita Plains and Siana than in the conservancies zone (Fig 31). On the Loita Plains this cattle density class occurred to the south east and centrally, near the source of the Talek River (Fig 31). In Siana, this cattle density class was widely distributed (Fig 31). In the conservancies zone, low-moderate cattle densities were evident to the north east of Talek town, along the boundary of Loita Plains and the Conservancies zone and to the south west and north west of Aitong town (Fig 31). Inside the Mara Reserve, low-moderate cattle densities were in the following areas: east of Oloolaimutia, east of Talek town, north west of Talek town and the south west corner of the Mara Triangle (Fig 31).

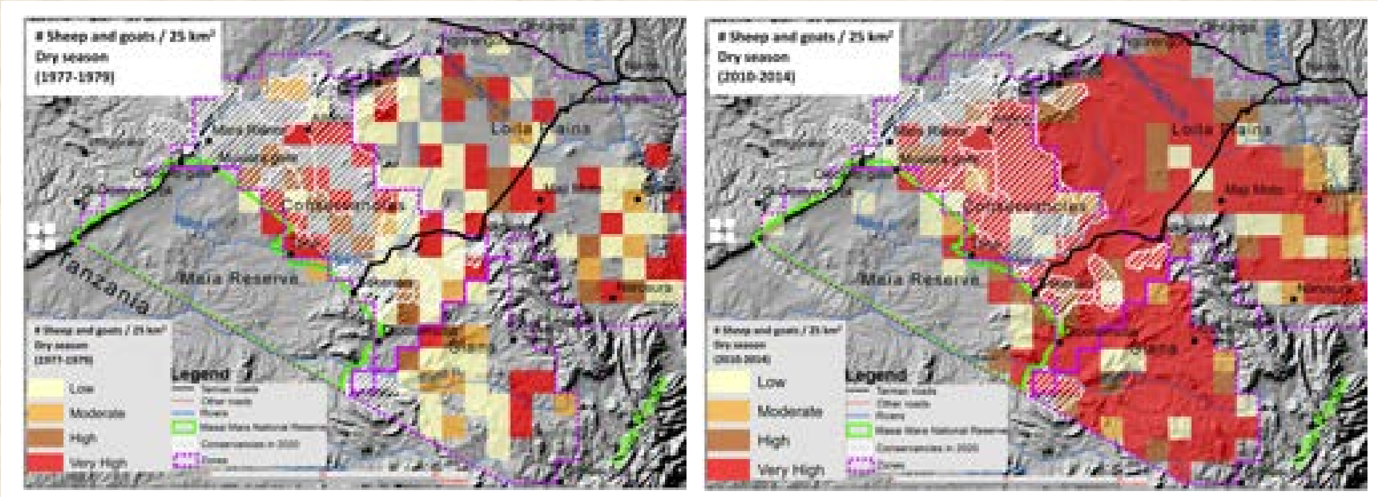

Fig 28. The distribution of sheep and goat density in the dry season during 1977-1979 and 2010-2014 grouped into low to high density classes defined by the 25th, 50th, 75th and 95th percentiles of the frequency distribution of their density from 1977 to 2018.

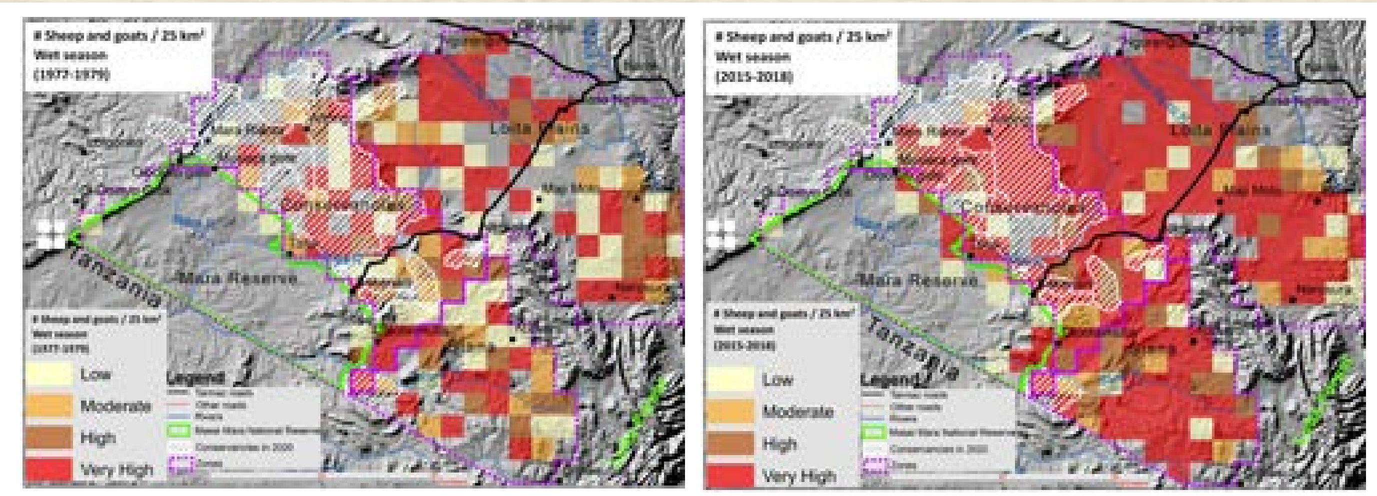

Fig 29. The distribution of sheep and goat density in the wet season during 1977-1979 and 2015-2018 grouped into low to high density classes defined by the 25th, 50th, 75th and 95th percentiles of the frequency distribution of their density from 1977 to 2018.

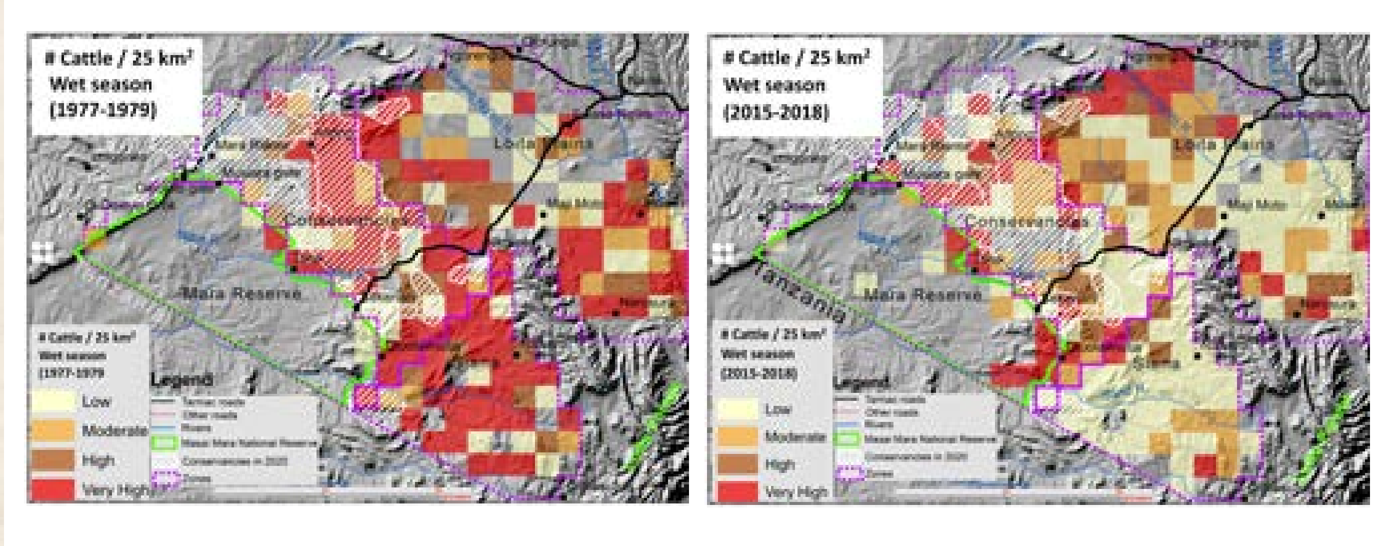

Fig 30. The distribution of cattle density in the wet season during 1977-1979 and 2015-2018 grouped into low to high density classes defined by the 25th, 50th, 75th and 95th percentiles of the frequency distribution of density from 1977 to 2018.

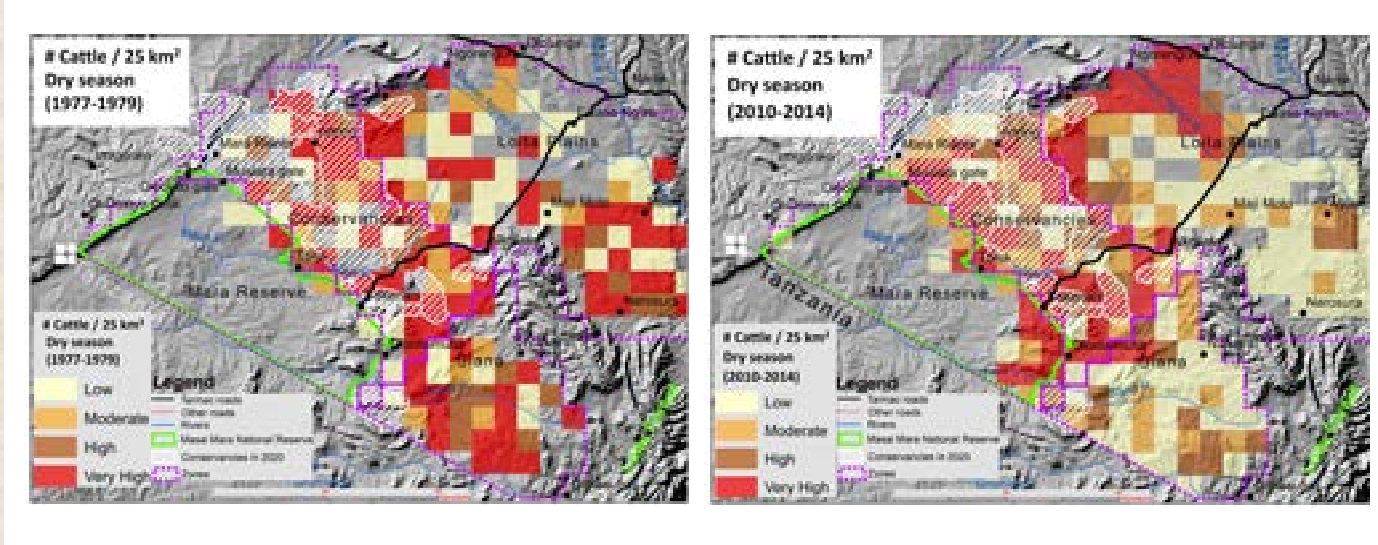

Fig 31: The distribution of cattle density in the dry season during 1977-1979 and 2010-2014 grouped into low to high density classes defined by the 25th, 50th, 75th and 95th percentiles of the frequency distribution of density from 1977 to 2018.

4.8. Hotspots of resident wildlife species in relation to the distributions of fences, sheep and goats

The number of resident wildlife species in the highest abundance class in the wet season during 1977-1979 was higher (4-9 species) in the Mara Reserve and the Conservancies zone than in the Loita Plains and Siana, both of which had no more than 4 species (Fig 32) except for a few areas in the Loita Plains and Siana which had 5-7. This indicates that the resident wildlife species prefered the Mara Reserve and the Conservancies zones to the Loita Plains and Saina in the wet season during 1977-1979. As a result of human population growth, privatization of land tenure and fencing, even the fewer resident species that preferred the Loita-plains have disappeared (Figs 32, 33). In particular, the recent rapid spread and intensification of fences have displaced the resident wildlife species from the Loita Plains (Fig 33). Although by 2020, far fewer fences were found in Saina compared to the Loita Plains, the abundance of the few resident species found in Siana had also declined (Fig 33), implicating the role of other factors than fences in their decline. In the Mara Reserve and Conservancies zone, the abundance of resident species had similarly declined during 2015-2018 relative to 1977-1979.

The reduction in the abundance of the resident wildlife species during 2015-2018 is likely due to intensifying competition for food and space with livestock, particularly sheep and goats whose population increased exponentially between 1977-1979 and 2015-2018 (Fig 29). Sheep and goats had displaced the resident wildlife species from the areas they preferred in 1977-1979 by 2015-2018 (Fig 34).

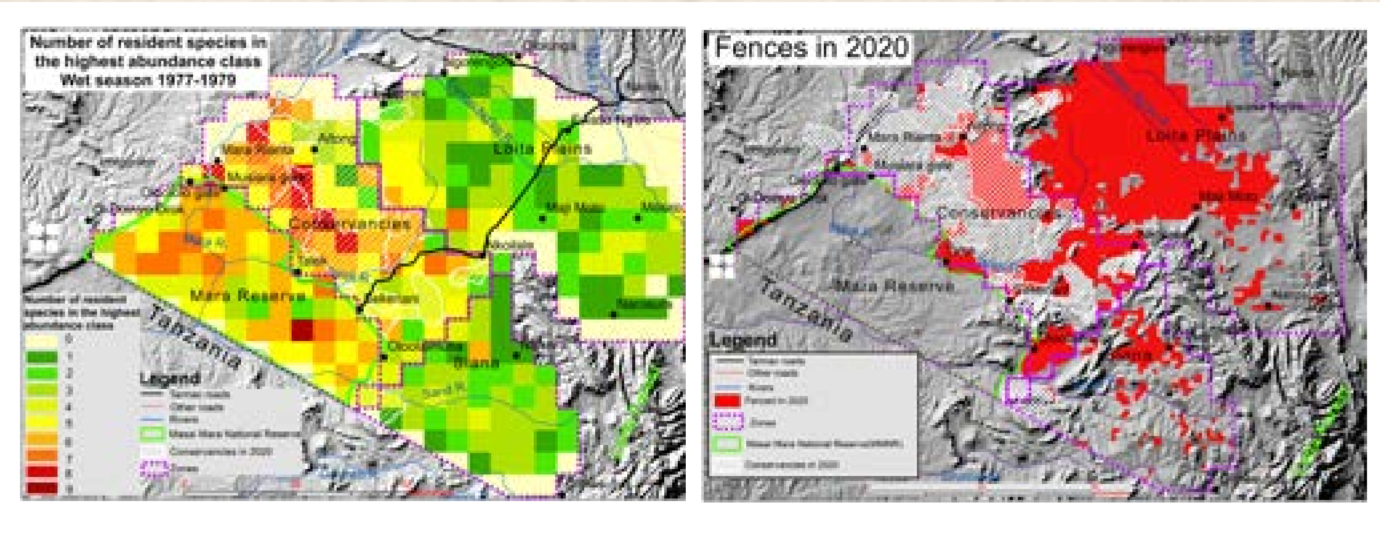

Fig 32: The number of the Mara-Loita resident species in the highest abundance class in the wet season during 1977-1979 and the distribution of fences in 2020. The maximum number of the Mara-Loita resident species is nine (Buffalo, Giraffe,Impala,Topi,Grant Gazelle, Waterbuck,Warthog and Ostrich).

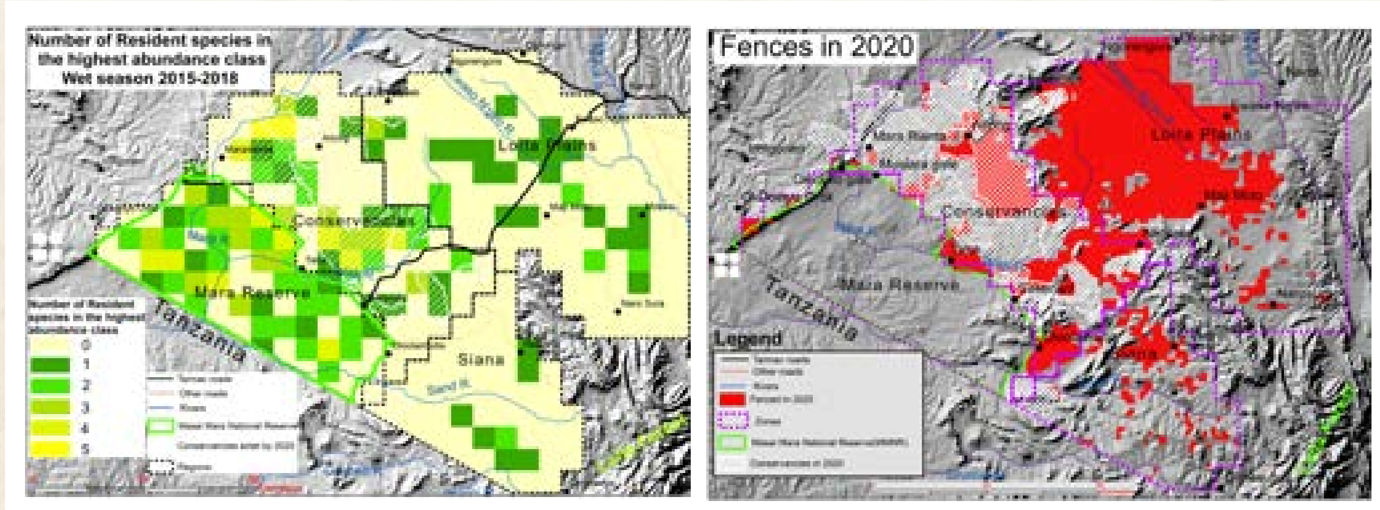

Fig 33: The number of the Mara-Loita resident species in the highest abundance class in the wet season during 2015-2018 and the distribution of fences in 2020. The maximum number of the Mara-Loita resident species is nine (Buffalo, Giraffe,Impala,Topi,Grant Gazelle, Waterbuck,Warthog and Ostrich).

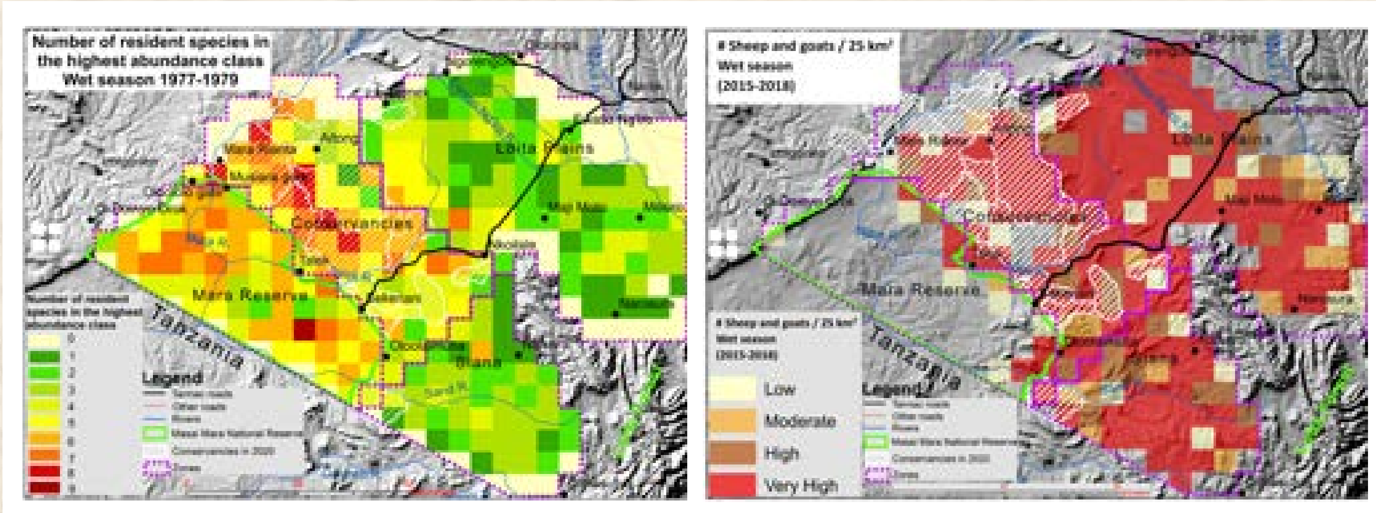

Fig 34:The number of the Mara-Loita resident species in the highest abundance class in the wet season during 1977-1979 and the distribution of density of sheep and goats in the wet season during 2015-2018. The maximum number of the Mara-Loita resident species is nine (Buffalo, Giraffe,Impala,Topi,Grant Gazelle, Waterbuck,Warthog and Ostrich).

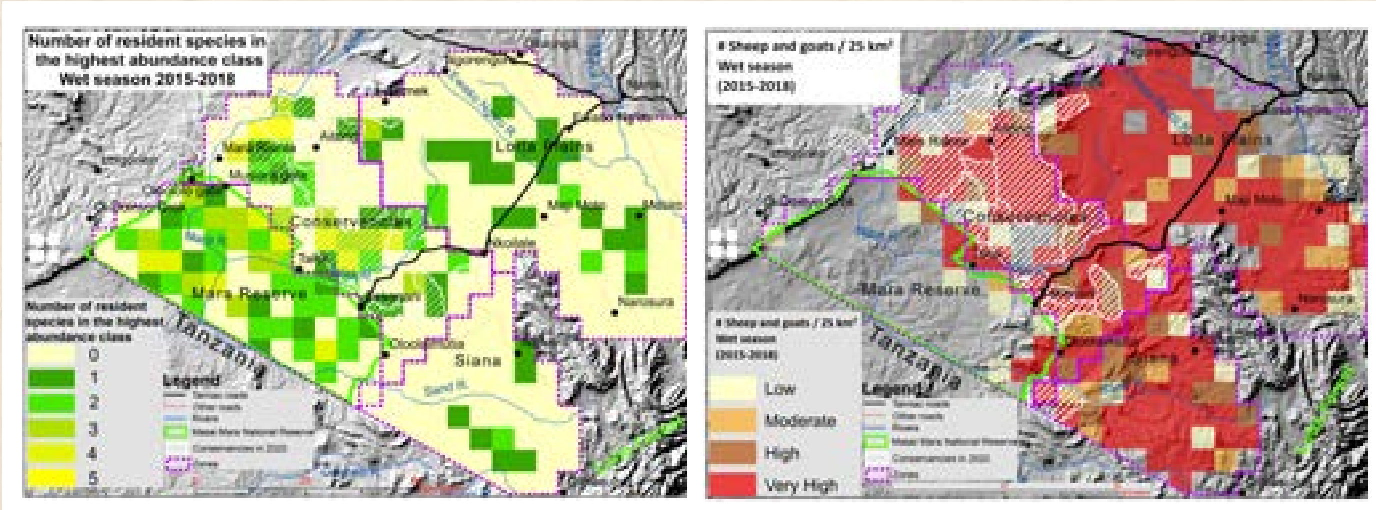

Fig 35:The number of the Mara-Loita resident species in the highest abundance class in the wet season during 2015-2018 and the distribution of the density of sheep and goats in the wet season during 2015-2018. The maximum number of the Mara-Loita resident species is nine (Buffalo, Giraffe,Impala,Topi,Grant Gazelle, Waterbuck,Warthog and Ostrich).

4.9. Recent climate change as a driver of land use change

Rainfall shows strong and sustained quasi-cyclic oscillation in both its wet and dry season components in the Mara from 1965 to 2020. Generally, the variation in the wet and dry season rainfall components are compensatory, meaning that when the dry season rainfall is high then the wet season component is low, and vice versa, thus resulting in a rather stable total average annual rainfall of about 1000 mm. The only exception to this general pattern since 1965 is the period 2010-2020 when both the wet and dry season rainfall components were in phase and well above the 1965-2020 average. This has created very wet conditions favorable to crop farming and livestock ranching in small, fenced individual parcels in this otherwise semi-arid area, with relatively variable rainfall. However, rainfall fluctuations in the Mara over the last half a century clearly show that such unusually wet conditions are transient and coincide with the wet phase of the 6-10-year cycle in local rainfall. The length of the current wet phase of the 6-10-year cycle has been unusually extended and the amount of rainfall greatly amplified by the intensified activity of the Indian Ocean Dipole, indicating the role of global warming in the current unusually high rainfall (Fig 36). The prevailing unusually high dry season rainfall was last witnessed in the Mara during the mid-1970s but the high wet season rainfall is exceptional and unprecedented in the Mara over the course of the last half a century (Fig 36). The wet season rainfall in the Mara is not only above the 1965-2020 average but is trending upwards since about 2003 (Fig 36).

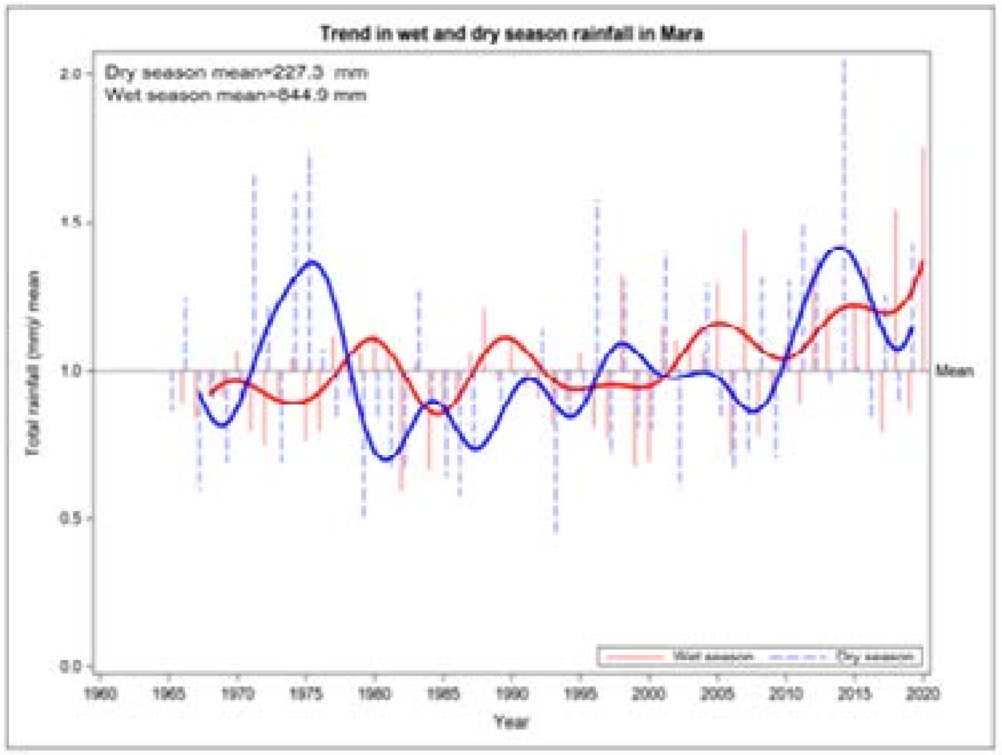

Fig 36. The fluctuation in the wet and dry season rainfall components (each divided by its long-term mean) in the Mara based on averages of 16 gauges from 1965 to 2020. The vertical needles are the observed seasonal deviations in rainfall whereas the solid curves are the 3-year moving averages.

The increase in rainfall is consistent with reports by Mara residents of increasing water availability in the more arid Loita Plains over 2010-2020 (Fig 37).

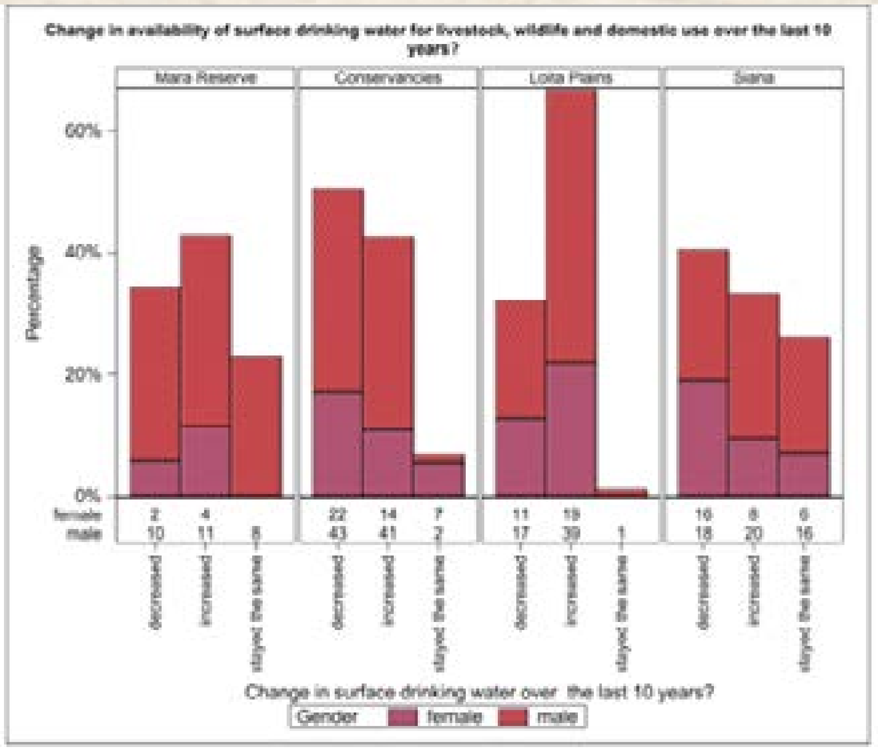

Fig 37. Mara residents report an increase in the availability of surface water in the relatively arid Loita Plains in recent times.

Despite the increasing rainfall trend, droughts are becoming more frequent (Fig 36) and intense (Fig 37) over time as also perceived by the Mara residents (Fig. 38,39). This is apparently paradoxical and suggests that intense and sustained heavy livestock grazing, range contraction such as by fences, and progressive deterioration are collectively reducing the efficiency of plant utilization of rainfall and increasing sensitivity to rainfall fluctuations of the Mara wildlife and livestock because of reduced per capita food availability.

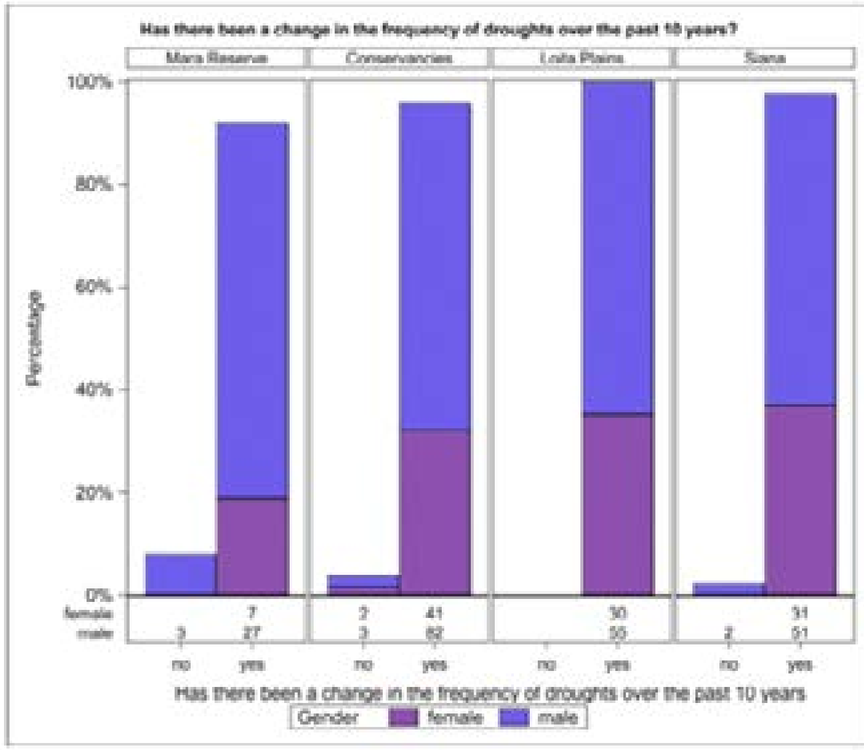

Fig 38. Mara residents perceive an increase in the frequency of droughts in recent times.

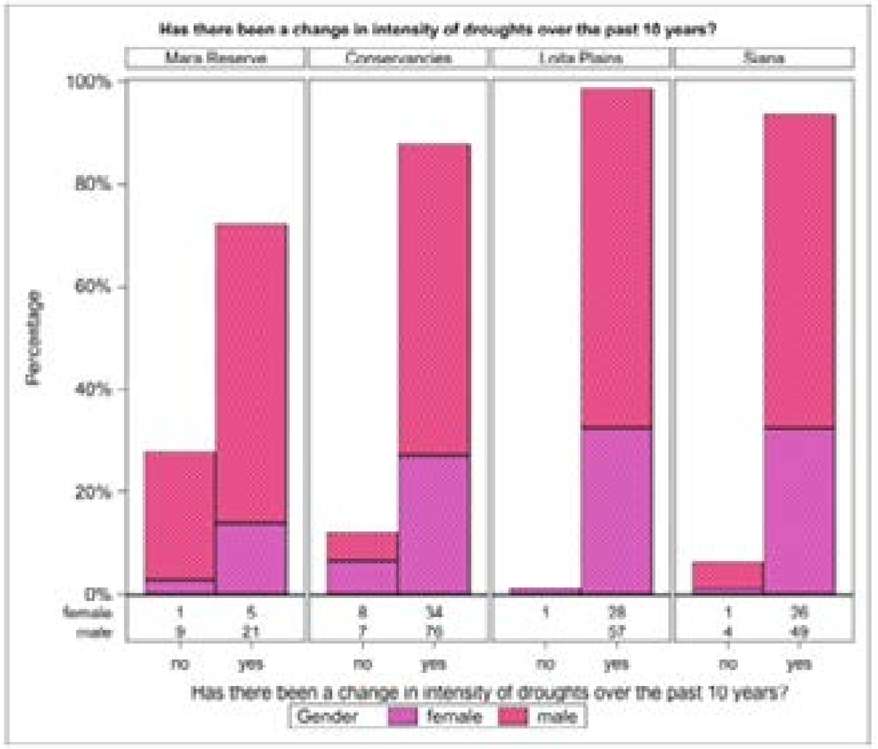

Fig 39. Mara residents report that droughts are becoming more intense in recent times.

The severity of the dry season is an important limiting factor for wildlife and livestock production in the Mara. We thus used the annual minimum greenness, averaged over each of the four study zones, to index the severity of the dry season in each year. The minimum greenness is usually reached in September of each year and has been measured since 2000 by the NASA MODIS remote sensing programme. The results show an overall increase in greenness since 2000, suggesting declining dry season severity (Fig. 40). This increase has been strongest in the Loita Plains. This increase has accelerated since 2015 in all the three landscape zones (Fig 40). Because the trend was the same for the Mara Reserve and the Loita Plains, this increased greenness cannot be attributed to more standing biomass because of fencing (that did not happen in the Mara Reserve), but instead reflects the effect of increasing rainfall. Combined with the recent land subdivision and the additional economic inputs in the region from government devolution, this may have tempted landowners in the Loita Plains to fence their land over the last 5 years, as sedentary ranching was made possible in this region by the increasing rainfall. However, the favourable conditions may be transient, due to the quasi-cyclic nature of rainfall in the region, where wet and dry periods tend to alternate every 6-10 years (Fig. 40). This means that if rainfall strongly declines over the next 5-10 years, this may lead to major trouble for the currently fenced sedentary livestock ranching, especially of sheep and goats in the Loita Plains. This may increase the need for additional income for landowners, such as through conservancies.

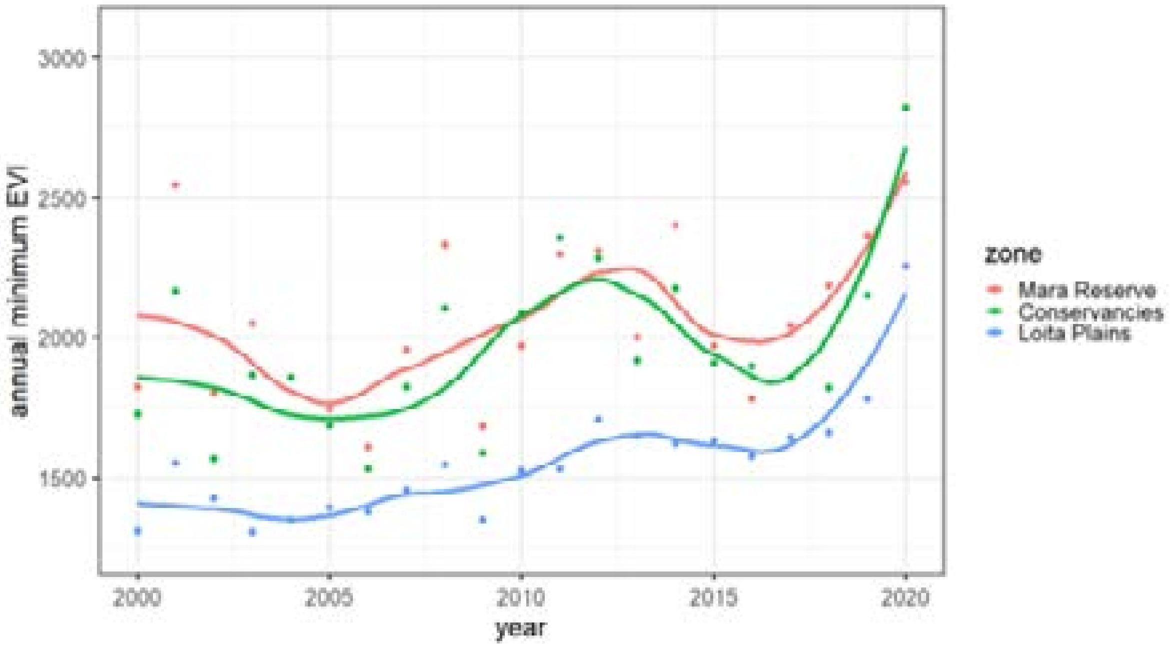

Fig 40. Trends in the minimum annual Enhanced Vegetation Index (EVI, and extended NDVI index measuring greenness of vegetation), calculated using 16-day MODIS composites, and spatially averaged over the three study area zones.

Even so, the Mara residents report a trend of earlier onset of vegetation browning in the dry season in recent times, implying progressive habitat desiccation (Fig 41). This likely reflects the effect on vegetation of intense and sustained livestock grazing and temperature warming. Indeed, both the temperature trend data (Fig 42) and the Mara community perceptions (Fig 43) provide compelling evidence of rising temperatures in both the maximum and minimum components.

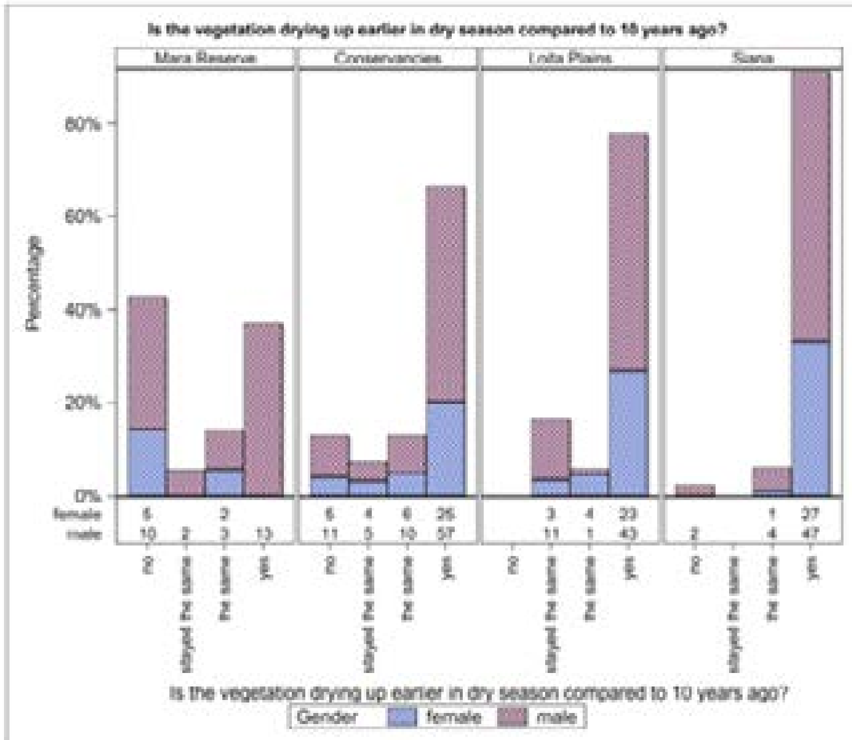

Fig 41. Mara residents report earlier drying up of the vegetation in the dry season in recent times.

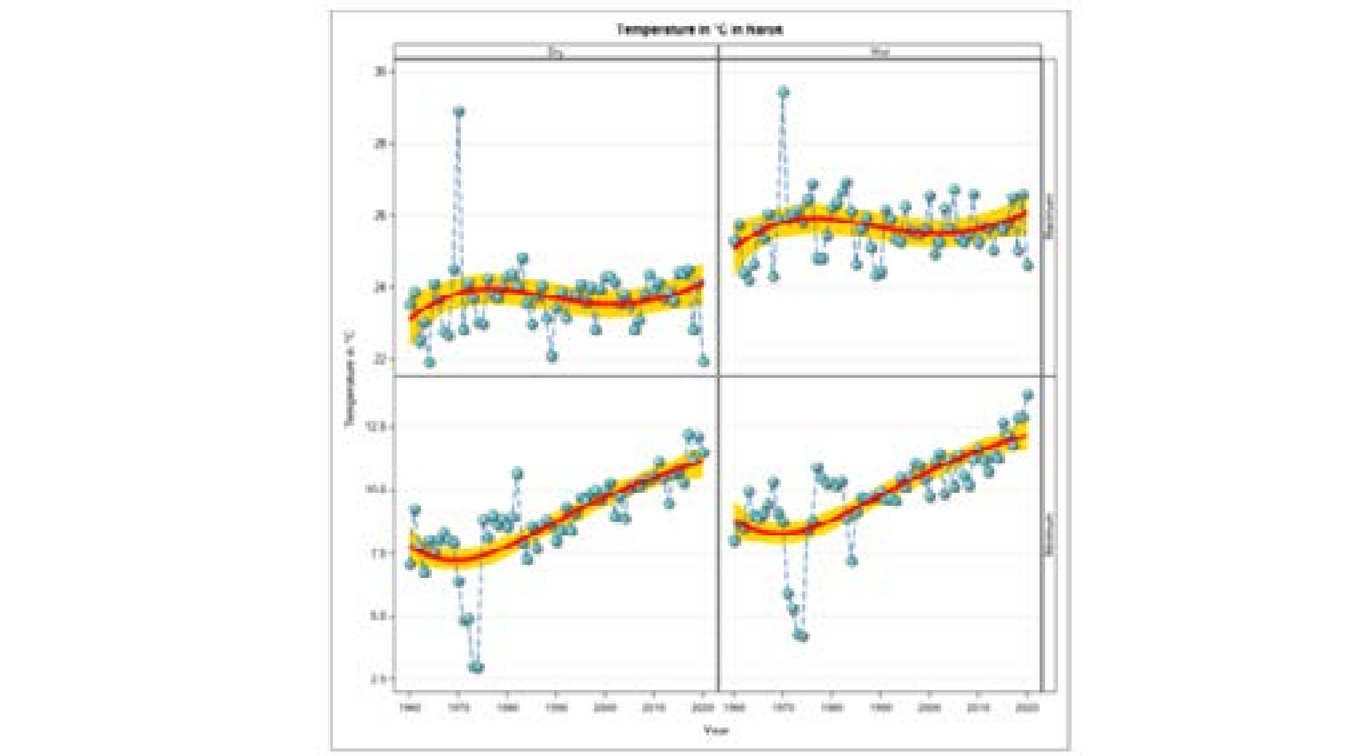

Fig 42. *The maximum and minimum temperatures are rising steadily in Narok since 1960 based on the data collected at the Narok Town meteorological station from 1960 to 2020. The cadetblue filled circles are the measured daily temperatures averaged across the wet (Nov-May) and dry (June-October) seasons in Narok Town.*

The red solid curves are the penalized spline smoothed temperature trends. The minimum monthly temperature has increased in Narok Town by 4.4 °C from an average of 7.1 °C in Jan 1960 to 11.5 °C in 2020 and continues to steadily increase.

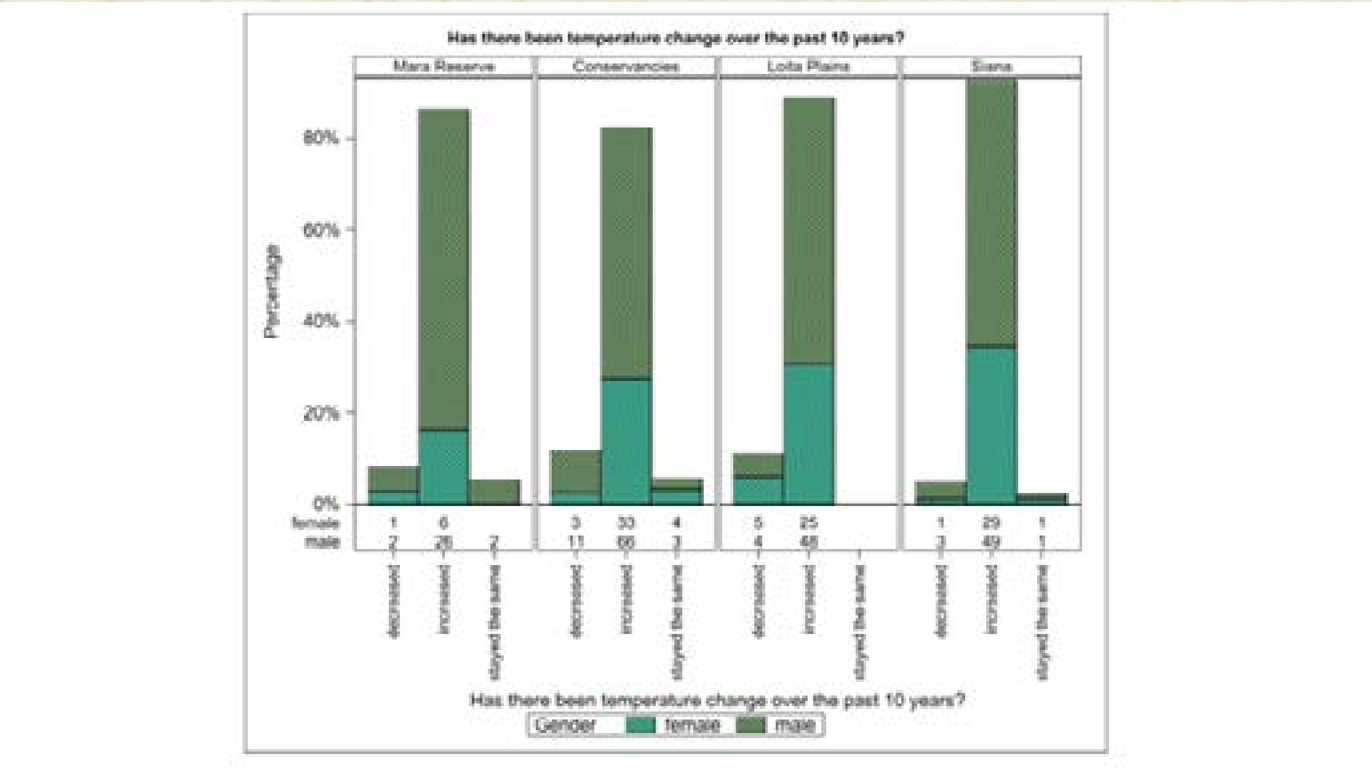

Fig 43. The Mara residents report an increase in temperatures in recent times.

5. SCENARIO ANALYSIS

In this section we present results of analyses of six scenarios concerning the priority areas in the Mara landscape where new conservancies could be established with the greatest impact on wildlife population recovery and ecosystem restoration. The approximate costs associated with each scenario are also provided. The constraints to establishing conservancies under each scenario are presented in the sections on the distributions of human population, livestock and fences.

5.1. Scenario 1

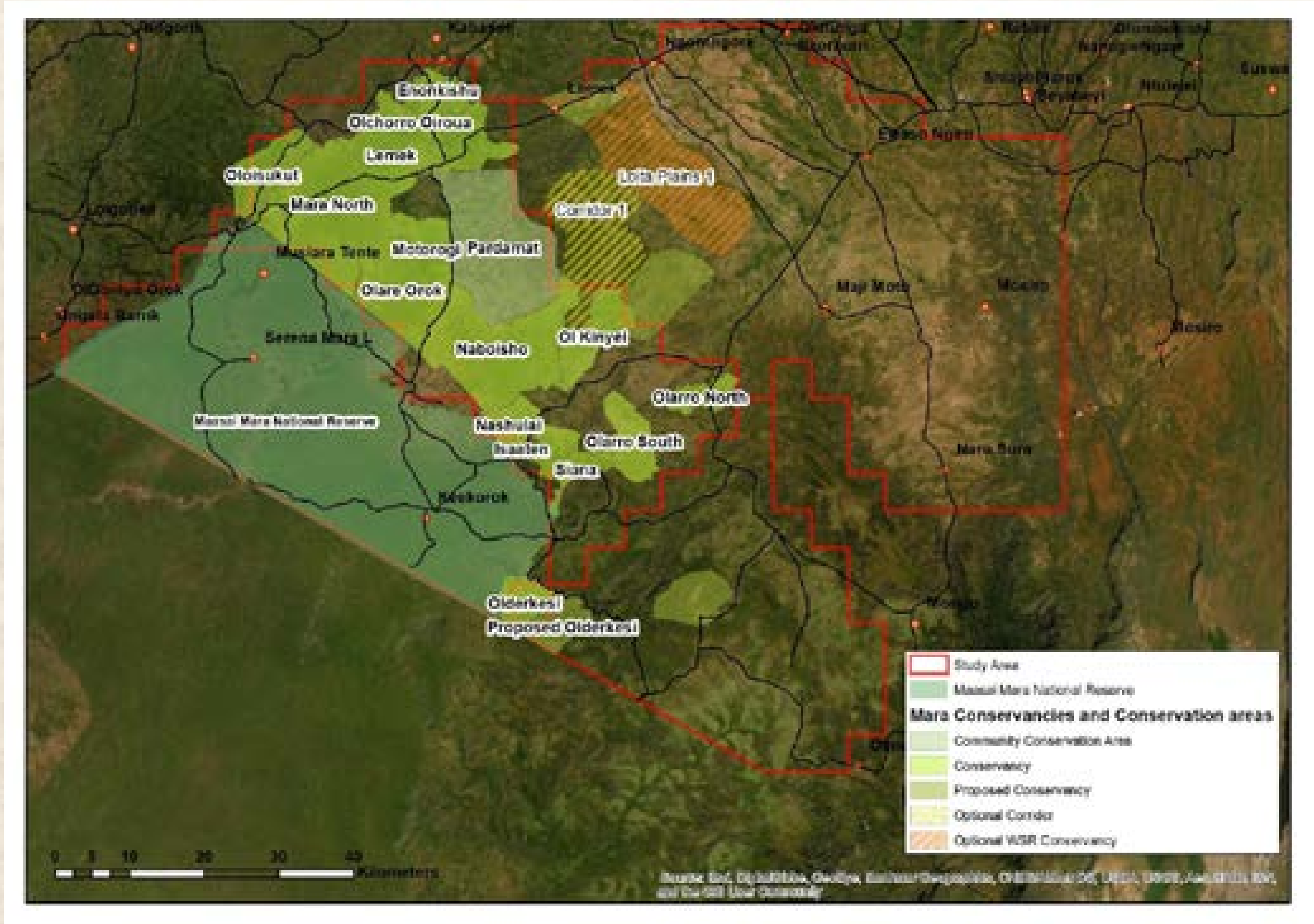

Figure 44: Scenario 1

This scenario involves the establishment of a new protected area of 406 km² in the previous primary wet season calving area of wildebeest in the Loita Plains (are "Loita Plains 1" in Fig 44, Table 1). The area connects from the current Mara Insinya conservancy, a protected area situated on a hilly area just adjacent to the Loita Plains and ends 4 km before the main road Narok-Sekenani. The Loita Plains 1 area is presently almost completely fenced and used for livestock ranching, while having hardly any cropland. The area can be a viable wet season range for at least 10,000 wildebeest again if all fences are removed. For this area to function again as a wet season range, it will need to be connected to the current conservancies (the dry season range) with a corridor. This scenario proposes a corridor (Corridor 1 in Fig. 44) that connects the current Naboisho conservancy to the Loita Plains. This combined Loita Plains protected area can be a viable wet season range for at least 10,000 wildebeest again if all fences are removed. Of the three possible corridors, this is likely the most ecologically promising corridor, as it connects to both conservancies and is a migratory route as it was used in the recent past by migratory wildebeest.

5.2. Scenario 2

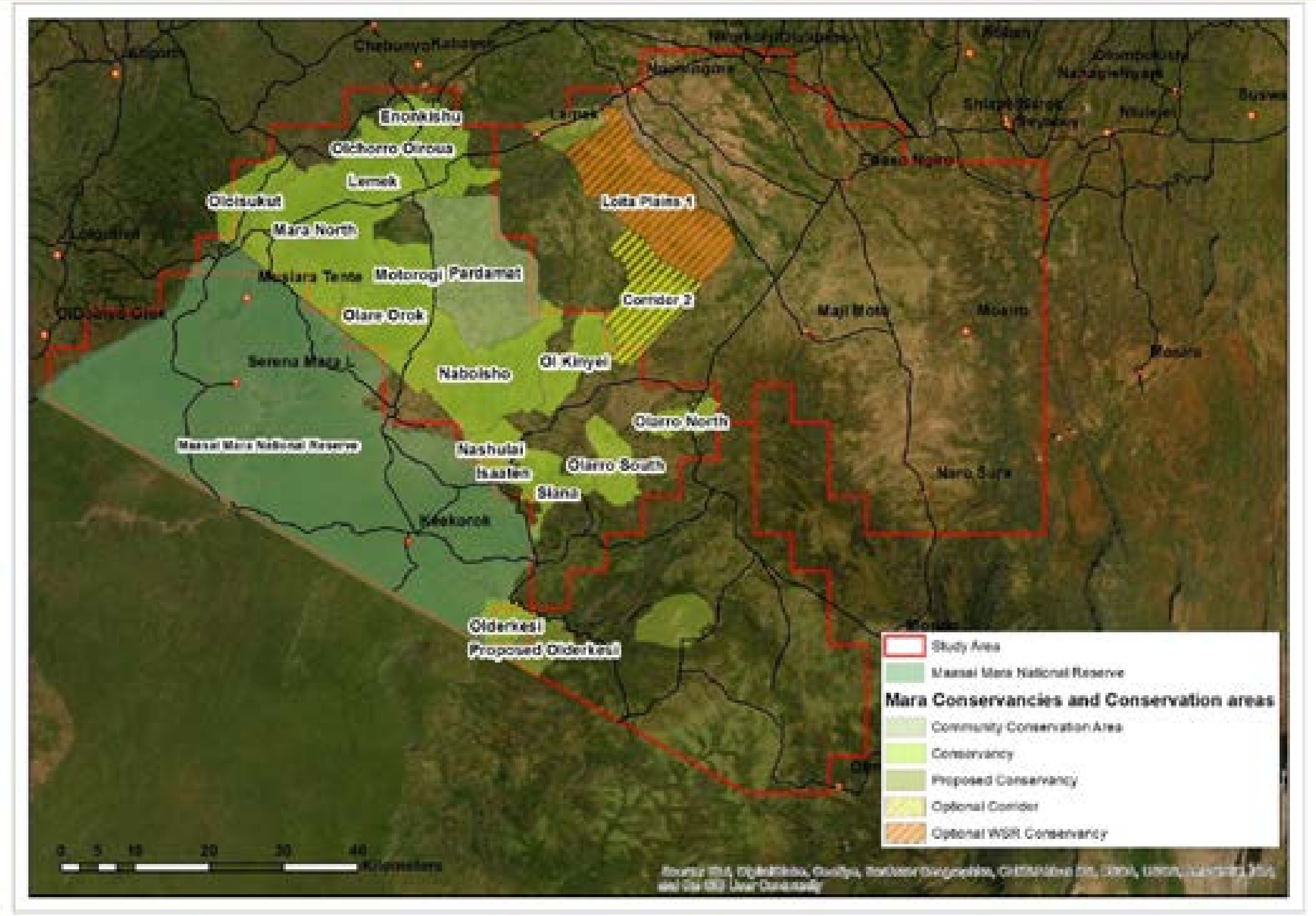

Figure 45: Scenario 2

Scenario 2 involves the same wet season range protected as Loita Plains 1 in the previous scenario, but is connected to the current Ol Kinyei conservancy through a different corridor of 354 km² (Corridor 2, Fig. 45, Table 1). This corridor mostly overlaps with the Muntoroben community conservancy area that is considered by MMWCA, which may increase its feasibility. This corridor 2 is currently almost fully fenced. An important advantage of both scenarios 1 and 2 are that they do not require migratory animals to cross the Narok-Sekenani tarmac road that may restrict movements (also due to its associated activities).

5.3. Scenario 3

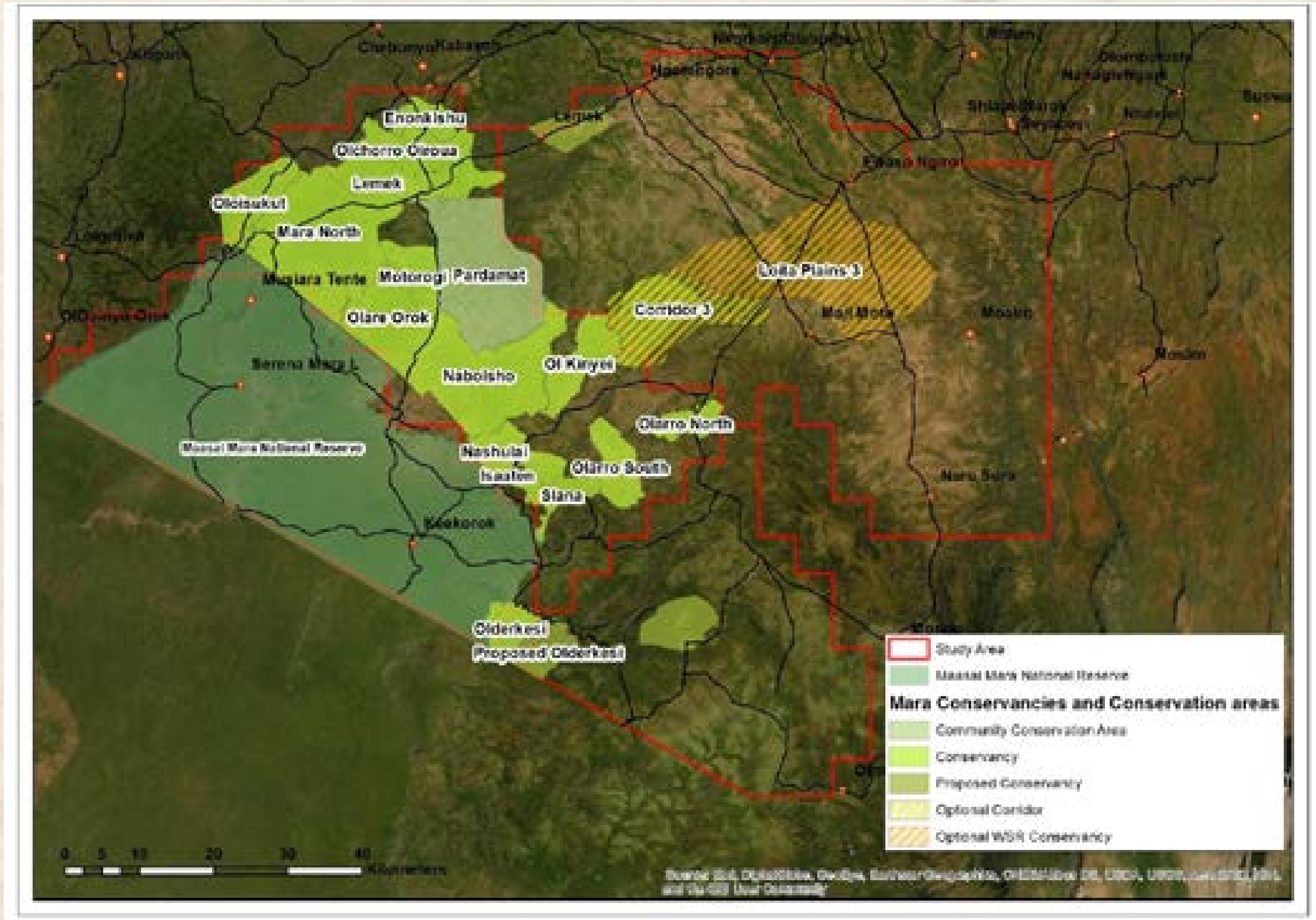

Figure 46: Scenario 3

In scenario 3, a different protected area is proposed for the Loita Plains wet season calving area: a 515 km² area situated between Maji Moto and Ewaso Ng'iro, situated left and right from the main road ("Loita Plains 3" in Fig 46). Like the Loita Plains 1 area, this area is now almost completely fenced. Connecting it to the dry season range of the migrations will require a different corridor ("Corridor 3" in Fig 46, Table 1). A downside of this scenario is that it will require the migrants to cross the main road that (with its associated activity) may repel them. This scenario could make the Maji Moto town into a new tourism hub associated with this conservancy but may also need to lead to restrictions of its further expansion (buildings, power etc) as historic movement analysis show that the migrants clearly stay away from busy settlements.

5.4. Scenario 4

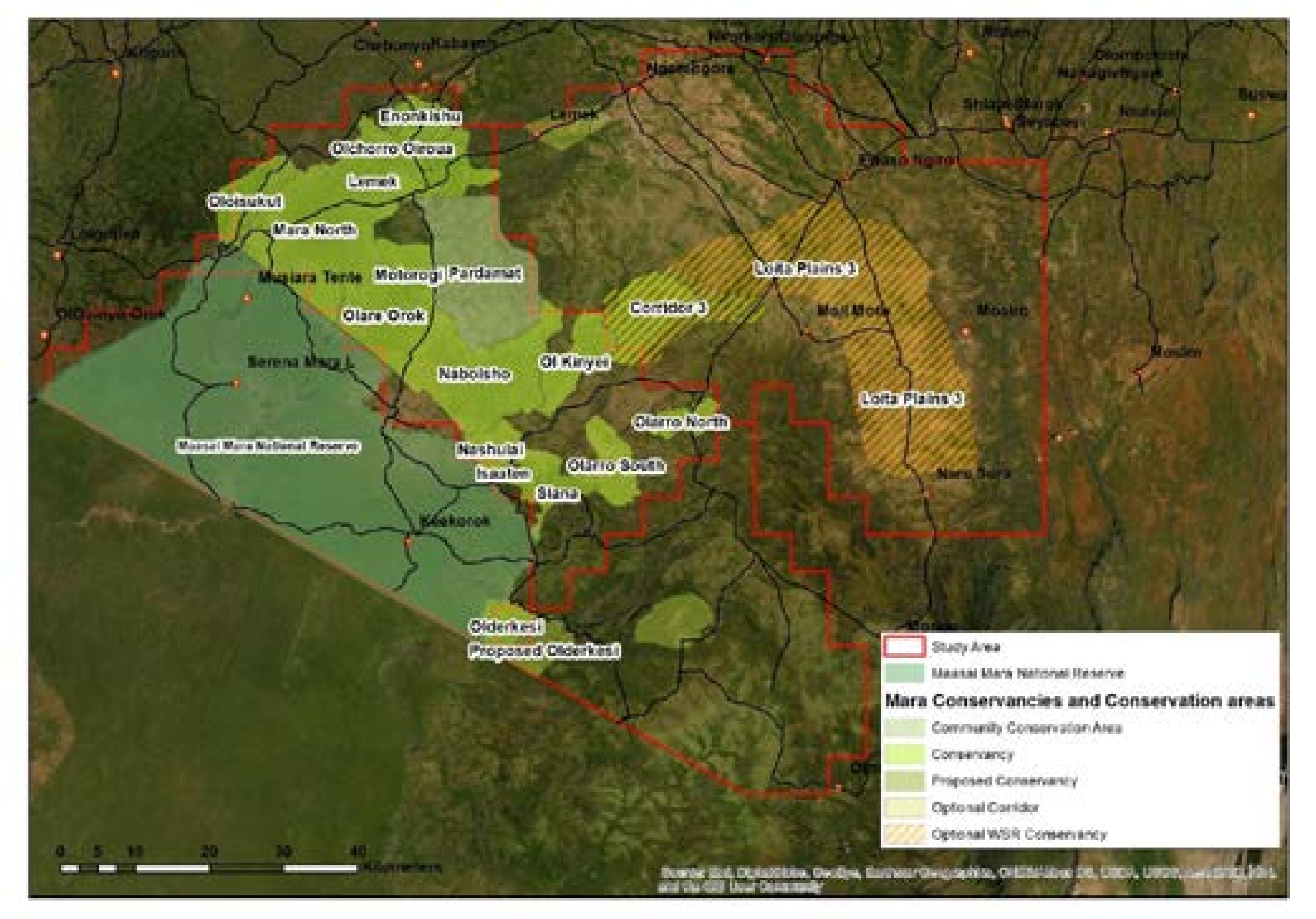

Figure 47: Scenario 4

This is an expansion of the previous scenario with an additional protected area in the Loita Plains stretching more south towards Narosura ("Loita Plains 3", Fig. 47, Table 2), covering 823 km². This Loita Plains 3 area has as a large advantage that it is not yet subdivided, the fencing is just starting in this area. This may lead to a larger susceptibility of the landowners for alternative scenarios towards the use of the land and associated income. However, due to its geographic position, this wet season range can only be connected to the dry season range through the realization of the previous scenario. It thus has the dilemma that in terms of spatial realization as a wet season range it is a next step, but in terms of opportunities to achieve its conservation it may come first.

5.5. Scenario 5

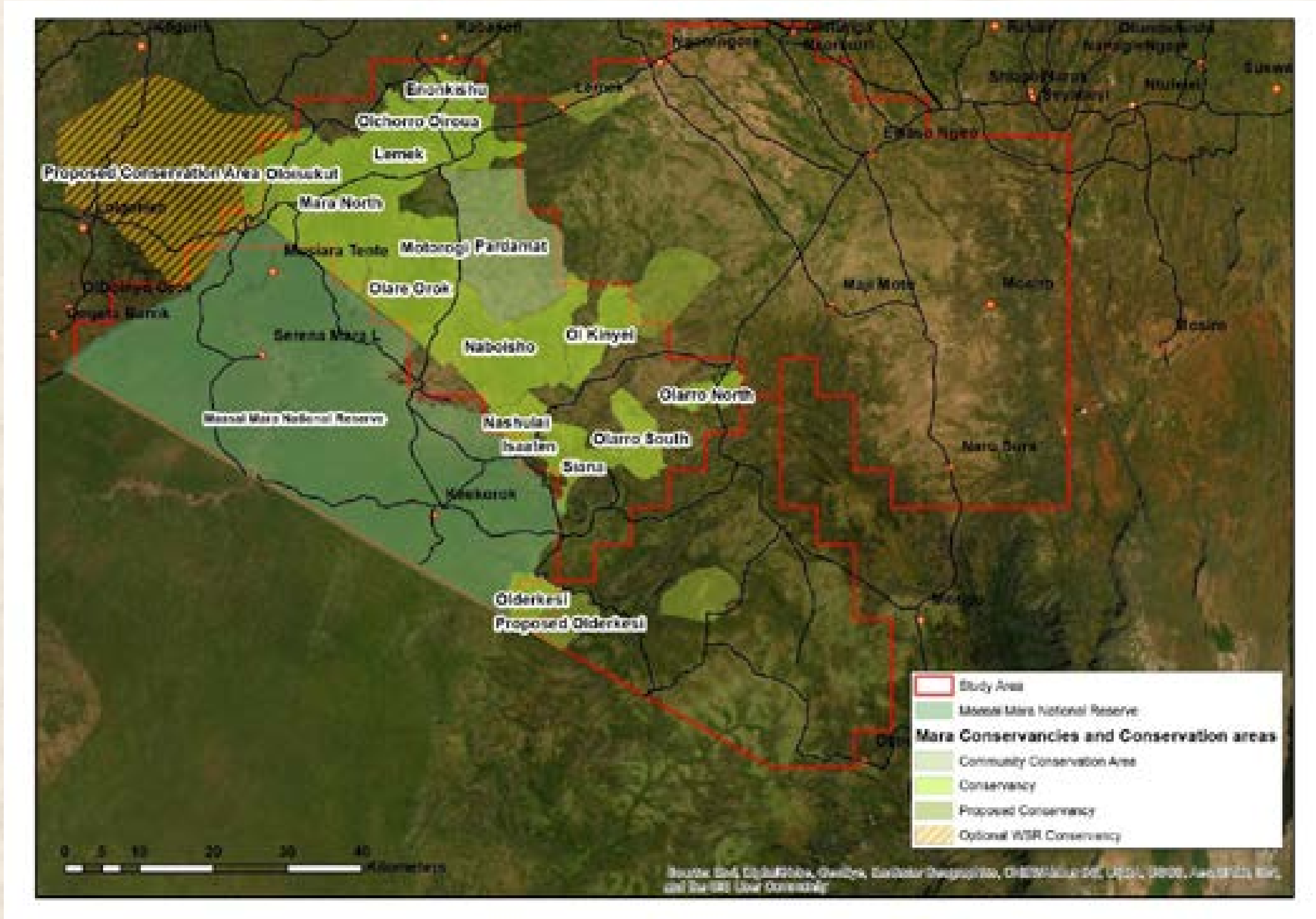

Figure 48: Scenario 5

Scenario 5 deviates from the other scenarios by proposing a conservation area encompassing Nyakweri Forest, covering approximately 523 km². This area is an active Elephant hotspot and crucial water tower, which highlights ecological importance. Currently, the forest is being somewhat protected, but is under threat from subdivision and thus fencing in the south, adjacent to the Maasai Mara National Reserve. There is a road passing through the proposed area which would strain wildlife crossing. There is also increased deforestation for charcoal production that directly threatens the forest, and thus highlights the need for it to be more intensively conserved.

5.6. Scenario 6

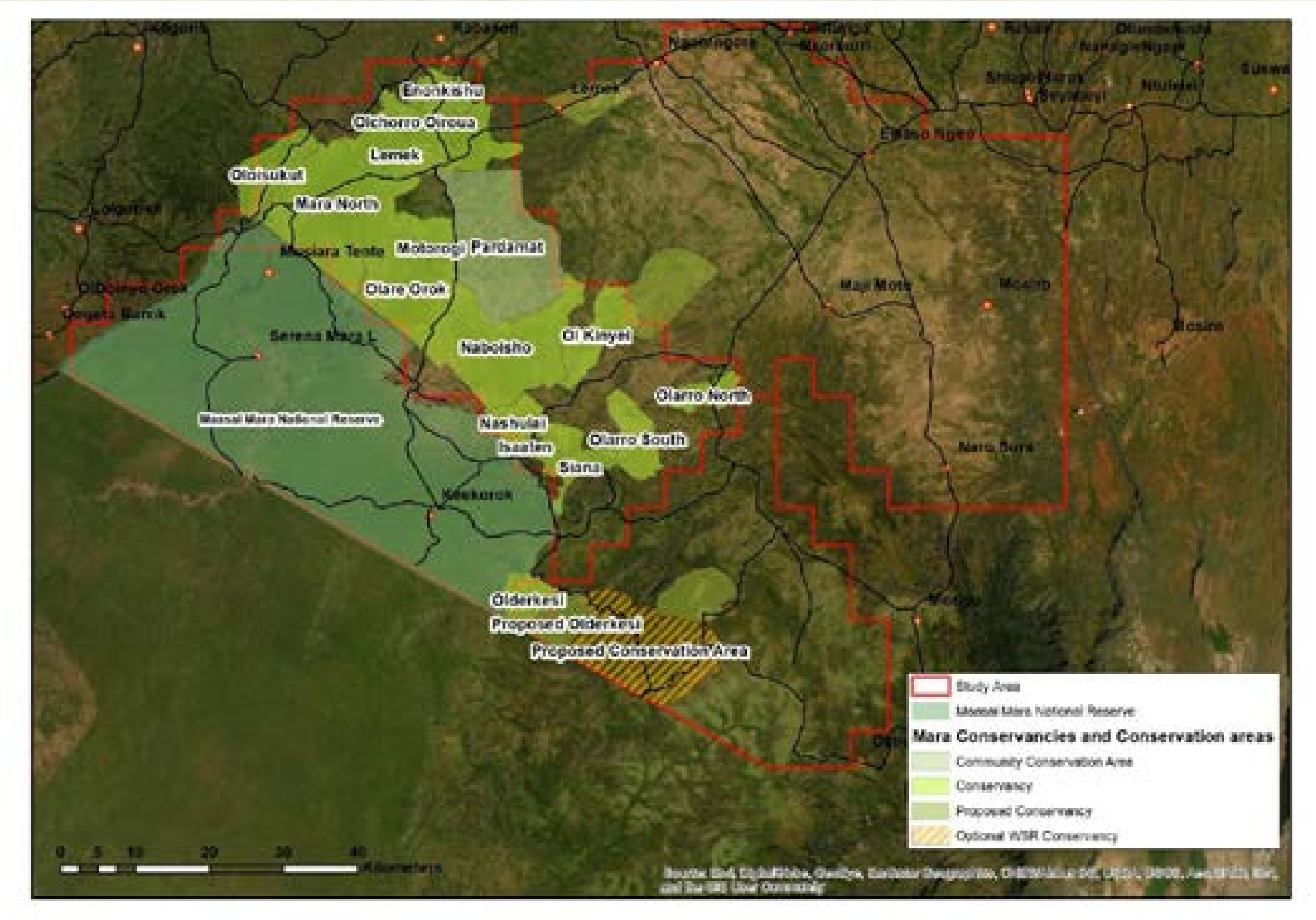

Figure 49: Scenario 6

Scenario 6 looks at the possibility of a conservation area or corridor by the Proposed Olderkesi which covers an area of approximately 197 km², which is an important route that connects Elephants from the Maasai Mara National Park and Mara conservancies to the Loita Forest. The population density of this area is significant in comparison to other areas suggested in the previous scenarios, but data shows that fencing is minimal, and thus the cost of fence removal would be lower than other scenarios. However, this area has a high density of livestock, which may influence community attitudes towards adopting conservation as an alternative or secondary livelihood. The already existing proposal to extend Olderkesi suggests an already positive attitude towards conservation in this area, which may make the adoption of this scenario easier in comparison to previously mentioned scenarios.

5.7. First cost estimates of the four scenarios

The true cost of the different scenarios will depend on the arrangement that is made with the landowners. If the current conservancies model is used, costs may involve the removal of fences, and land rents paid to landowners, to be raised by a revenue model. As most animals will visit the area in the wet season (November-June) this makes high income from western tourism less feasible than for the dry season range. The price per scenario ranges between USD 310,000 TO USD 1.3M.

The indicative purchase value of the land of the four scenarios at the current price level ranges from KES250k an acre to KES 5M per acre. Purchase of the land will only be possible through cooperation of all landowners which will drive up the price. It will also require the full prioritization of this alternative land use by the Narok County Government.

Table 2: Cost Analysis for the Proposed Scenarios

Part of scenario	Scenario component (see maps figs 44-47)	Size (acres)	Land rent value (eur/ yr)[1]	Approx. no. of land-owners[2]	Pros	Cons
1	Corridor 1	43,490	439,995	435	until recently used by migratory wildebeest	strongly fenced, subdivided now
1,2	Corridor 2	30,641	310,000	306	partially overlaps with proposed (by MMWCA) Muntoroben conservancy	strongly fenced, subdivided at the moment
3,4	Corridor 3	39,537	400,002	395	yield option for connection to the southern Loita Plains, which are still largely unfenced	crossed the tar road Narok-Sekenani and associated activity, may repel wildebeest
1,2	Loita Plains 1	56,834	574,998	568	highest annual rainfall, most wildebeest expected here, no major road crossing needed	strongly fenced, subdivided
3	Loita Plains 2	69,935	707,543	699	no major road crossing needed	strongly fenced, subdivided

4	Loita Plains 3	87,722	887,497	877	not yet completely fenced, subdivision in progress	not an independent corridor to the dry season range possible, can only be connected to the dry season range through Loita Plains 2, making this an expensive option
5	Proposed Conservation Area	129,236	1,307,500	1292	Already gaining conservation attention from stakeholders	Subdivision and charcoal production are in progress
6	Proposed Conservation Area	48,680	492,503	487	Next to proposed Olderkesi extension	High livestock activity

[1]assuming an average annual rental value of USD25/Ha
[2] assuming 100 acres/person
[3] assuming each landowner has fully fenced and has paid for half of the fences they share with their neighbor

5.8. Five rapidly growing towns in the heart of the Mara ecosystem as threats to its conservation

In addition to securing the necessary funding and community support, there is another current key threat to sustaining the biodiversity of the Mara ecosystem through these scenarios. In the heart of the Mara ecosystems five towns (former shopping centres and gates) are now very rapidly growing: Mara Rianta, Talek, Sekenani, Oloolaimutia and Nkoilale (Fig. 48). Their growth is spurred by the recent infrastructure improvements: the tar road Narok -Sekenani and the improved road Narok - Mara Rianta. This leads to growing problems with drinking water, pollution from sewers and overall wildlife disturbance, impairing the promise of future ecotourism revenues that accelerated the development of these towns in the first place. Spatial planning is urgently needed to evaluate and potentially control these rapid developments. The rapid expansion of Nkoilale shopping center raises similar concerns.

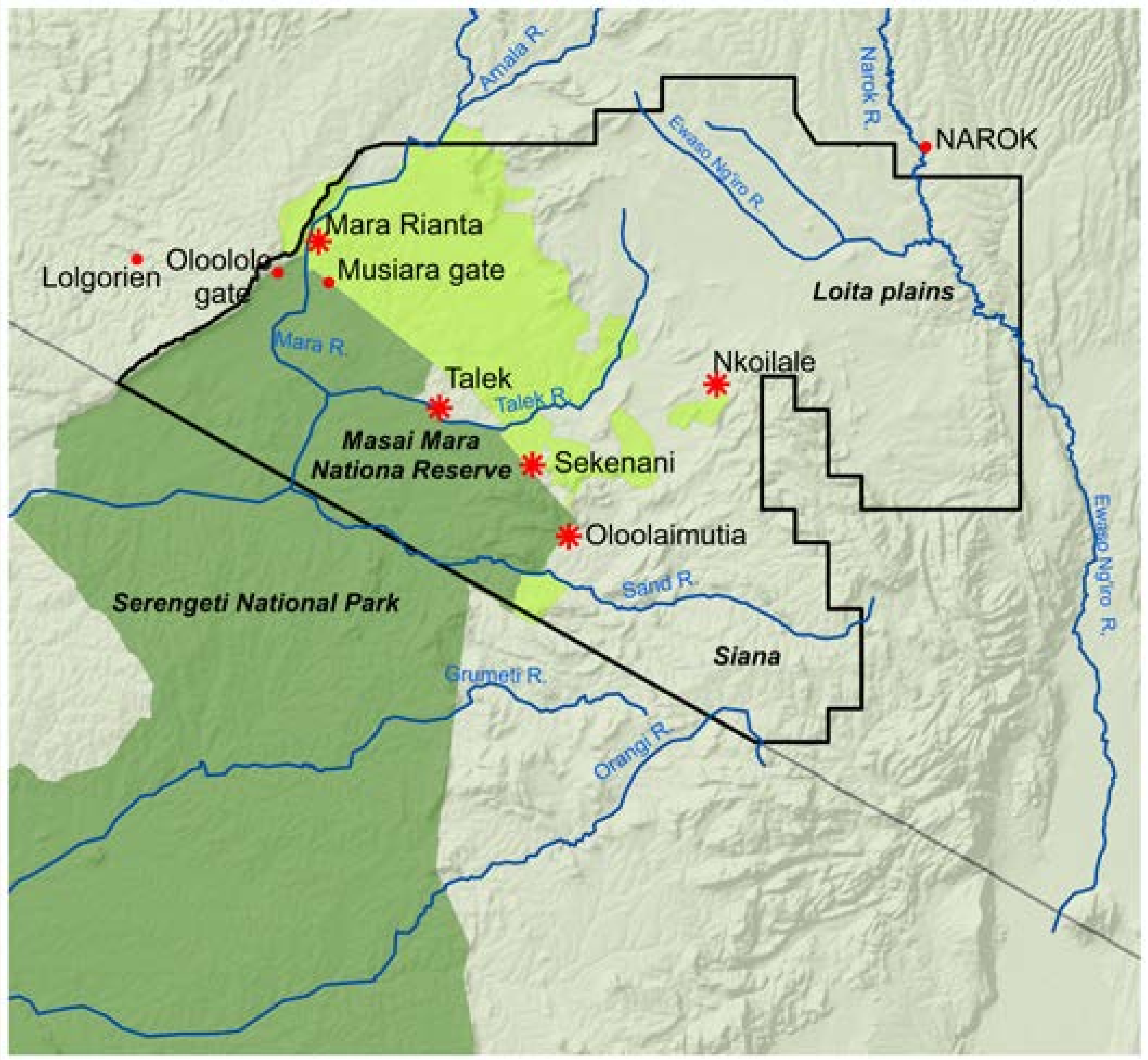

Fig. 48: Five rapidly growing towns in the heart of the Mara ecosystem.

5.9. Policies on wildlife conservation, land use and land tenure

Government policies on wildlife conservation, land use and tenure have been at best uncoordinated and at worst contradictory, leading to incongruent land uses and the loss of wildlife and their habitats. Government policies have promoted wildlife conservation, cultivation, and individualization of land tenure all in the same areas. It is incomprehensible that Government policies have promoted wildlife conservation and tourism, large-scale, mechanized commercial wheat and barley farming in the prime wildebeest calving and wet season concentration areas in the Loita Plains in Ngorengore and Ololunga, as well as land privatization in the Mara. The wet season range, which is also the calving area for the Mara-Loita wildebeest, zebra, Thomson's gazelle, and eland is now all but gone. This has been a result of deliberate government policies first encouraging the formation of group ranches and large-scale farming in the ranches by leasing land out to European and African farmers. These farmers were driven purely by the profit motive and used heavy machinery and considerable fertilizers to maximize profits and did not invest in preserving the fertility of the land. Once the land had become degraded and unproductive, they simply moved on to the next available lands and caused destruction of the wildlife habitats and the land for short-term profit, leaving the group ranches worse off than they had found them.

When group ranches were created in the late 1960s and early 1970s, the Government was aware that conflicts with wildlife would be raised and directed that "no rancher in the adjudicated areas in Narok and Kajiado should be required to sustain wildlife on his land if this means lower returns". This official license to eliminate wildlife while also promoting tourism and many other examples demonstrates the need for better coordination of policies across bureaucratic lines.

The Kenyan state also owns the wildlife, including on private land while private citizens own land and are not permitted to use or own the wildlife but are free to destroy the wildlife habitats. As a result, there is no clear policy on fencing, which has proliferated at unprecedented rates in the Mara and elsewhere in wildlife habitats, for example in Athi-Kaputiei, Amboseli and Laikipia, causing irrevocable destruction of the habitats for wildlife, pastoralist commons and livelihoods.

5.10. Institutions and Governance Structures

Wildlife conservation on private land in Kenya has suffered immensely because of institutional and governance failures. Four state institutions have been responsible for wildlife conservation in Kenya since 1901. The first was the Game Department (GD) from 1901 to 1976. From 1945, the trustees of the Royal National Parks (RNP) were mandated to manage wildlife in national parks and national reserves. The mandate of the Game Department was reduced to overseeing wildlife conservation on trust lands under the local African District Councils, later renamed County councils. In 1977 both the Game Department and the Royal National Parks were merged to form the Wildlife Conservation and Management Department (WCMD). After all big game hunting was banned on 20th of May 1977 because of excessive slaughter of wildlife, WCMD was unable to effectively protect wildlife. The institution was allegedly steeped in so much corruption that it was unable to discharge its duties effectively. WCMD was so inept and corrupt that the period 1977-86 is aptly referred to as the lost decade --through poor management and corruption. During its tenure, many ranger posts and checkpoints were closed, leaving wildlife with no protection. These ranger posts were never to be reinstated. Yet, it was not until 1989 that WCMD was disbanded to pave way for the formation of the Kenya Wildlife Service (KWS). KWS sees its role outside the state protected parks and reserves as merely advisory and has no ranger presence on private lands. The Narok County Council kept some rangers in lodges to protect tourists outside the Mara Reserve and virtually none to protect wildlife. In a nutshell, the Government long abdicated its responsibility of managing and conserving wildlife on private land, which supports most of Kenya's wildlife. The vacuum created by these institutional, governance and market failures began to be filled by conservancies around 2005.

6. DEVIATION OF PLANS

Human population data for 2019, which was initially needed for the suitability analysis, was not geographically linked, due to differences in boundary shapefiles that the project had access to. Because of this, the use of human population data in this analysis has been replaced with fencing data. Fencing data is more accurate in depicting the breaks in the physical connectivity of the landscape, and thus the potential conservation areas available.

The study initially aimed to assess the change in land tenure over time. However, access to land tenure information has proven difficult, largely due to government bureaucracy.

7. FOLLOW-UP AFTER THIS FEASIBILITY STUDY

As already discussed in this document, analysis has led to the creation of 6 viable scenarios regarding the conservation potential of the greater Mara ecosystem. These scenarios outline possible routes for bending the curve of biodiversity loss as currently observed in the Mara towards more sustainable management of this unique ecosystem. Regarding the follow up now needed, Table 2 outlines that after the current feasibility study phase of this project, there are two important next steps to be taken. First, the current feasibility study should be extended to results in a detailed project plan.

Table 3: Necessary steps in project development to restore migration to the Loita Plains and bend the curve of current biodiversity loss in the Mara Ecosystem

Phase	main deliverable
1. feasibility study (this study)	explore the feasibility of a project aimed at restoring the northern migration and associated biodiversity and livelihood improvement
2. project plan development with stakeholders and scientific underpinning	Develop a full and detailed project plan for restoring the northern migration to the Loita Plains and associated livelihoods of people, with extensive stakeholder involvement (land owners, authorities, conservation organizations, tourism industry), scientific analysis of the deeper causes of wildlife decline (importance of climate change, livestock, markets, socio-cultural factors, policy, governance, law enforcement, land tenure change, human population growth, infrastructure development, institutions) to develop long-term solutions, expected biodiversity benefits, economic feasibility study, sustainable business model, governance model, and recommended scenario of choice, organization and presentation of all information in online spatial web mapping and planning tools. The proposal here is to continuously monitor the ecosystem to establish a baseline, indicators and assess changes in the ecosystem. First cost estimate: 1 million Eur.
3. Secure the funding for the project plan	Using the detailed project plan, this phase regards the securing of the funding for the implementation phase of the project. Funding will focus on continuous assessment of the ecosystem and working towards securing corridors and conservation areas.
4. Project plan implementation	implementation phase of the recommended scenario: establishment of a corridor and wet season range protected area at the Loita Plains

8. CHALLENGES

The primary challenge to the implementation of this study has been the acquisition of data, to fulfil specifically the goals of work packages 1 and 3. This is the case particularly with temporal data on land tenure and human demographics.

9. OTHER FUNDING AGENCIES AND SUPPORT TO THE PROJECT

The project team members and authors of this report contributed substantially to this report by donating their time and data resources. Specifically, Prof. H. Olff (University of Groningen, The Netherlands) has made a substantial contribution of his valuable time for free to the scientific development of this project. The project has significantly profited from the extensive aerial survey dataset collected by DRSRS over the past 41 years. Staff time for One Mara Research Hub staff and Kenya Wildlife Trust staff was covered by organizational costs.

Reversing the disintegration of the Mara Ecosystem: A feasibility study

ONE MARA RESEARCH HUB

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