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Megaherbivores and Mega-Infrastructure in East Africa

Fredrick Lala[1,2] | Joseph K. Bump[1]

[1]Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, Saint Paul, Minnesota, USA | [2]Wildlife Research and Training Institute, Naivasha, Kenya

Correspondence: Joseph K. Bump (bump@umn.edu)

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ABSTRACT

Massive infrastructure development impacts ecologically important, culturally iconic, and economically vital populations of megaherbivores in East Africa. The seven member countries of the East African Community (EAC) have multiple hypercomplex road, rail, and port projects planned that will cross essential habitats for elephant, giraffe, rhinoceros, and hippopotamus populations, all but one of which range from threatened to critically endangered in global extinction risk status. Within the EAC, concerns have been raised about effective and efficient development mitigation and shared biodiversity conservation governance. Scalable solutions have been demonstrated in some EAC countries, but there is a vital need for regional policy. The acute challenge of megaherbivore conservation amid mega-infrastructure development in East Africa can best be addressed with the fulfillment of an EAC wildlife sector coordinating unit.

Balancing wildlife conservation and development is an especially "wicked problem" (DeFries and Nagendra 2017) when the animals and the infrastructure projects involved are super big. Nowhere else is this problem more acute, nor is mitigating policy more needed, than in the East African Community (EAC), a regional organization of seven partner nations comprising Burundi, the Democratic Republic of the Congo, Kenya, Uganda, Rwanda, South Sudan, and Tanzania. A wildlife sector coordinating unit is needed now more than ever in the EAC to help address potential negative impacts by directing conservation policy. Formation of such a unit is supported by finalization of key biodiversity-related requirements of the Treaty for the Establishment of the EAC.

Lands within the EAC are home to ecologically and economically important and critically endangered megaherbivores (mammals with an adult body mass usually >1000 kg; Owen-Smith 1988). Living terrestrial megaherbivores in Africa include all species of elephant (*Loxodonta* sp.), rhinoceros (*Diceros* spp., *Ceratotherium* spp.), hippopotamus (*Hippopotamus amphibius*), and giraffe (*Giraffa* spp.). Very large body size distinguishes the ecological role of megaherbivores, and they disproportionately influence ecosystem health and functioning (Hyvarinen et al. 2021). Wild megaherbivores are also a major tourist attraction, anchoring a wildlife tourist industry that generates billions of dollars and accounting for ~10% of GDP regionally in the EAC (Okello 2014). The EAC is home to all of the world's critically endangered East African black rhino, all of the world's reticulated and Masai giraffe species (both endangered), about a quarter of Africa's elephants (forest elephants are critically endangered and Savannah elephants are endangered), about 3% of the world's near-threatened white rhino, and nearly 40% of world's common hippopotamus population, which are listed as vulnerable. These populations within the EAC are critically important to the conservation of megaherbivore species.

Both authors contributed equally to this work.

The EAC is also home to multiple mega-infrastructure projects, which are hypercomplex development plans with profound economic, political, social, technological, and environmental impacts on society (Chen et al. 2022). The expansive scope and very large costs (currently "trillion-level era") of mega-infrastructure development disproportionately influence national and international policy. These are geopolitical projects that garner multinational investment. In Kenya, there is a mega-infrastructure corridor linking Nairobi, the capital and largest city in the country, to Mombasa, the country's largest seaport (Figure 1). This corridor serves interior Kenya and her neighbors in the EAC (Irandu and Owilla 2020). Running through this corridor are a meter-gauge railway, a highway, oil and water pipelines, a high-voltage powerline, and a recently completed mega-infrastructure project—the standard-gauge railway (SGR; Lala et al. 2022). Phase I of Kenya's SGR from Mombasa to Nairobi was the largest infrastructure project since national independence and additional phases are planned (Irandu and Owilla 2020). There is also a designated Mombasa–Nairobi Expressway, a four-lane toll highway with expected completion in 2026. In Tanzania, the Central Corridor Project is a ~2200-km network of roads, railways, utilities, and inland waterways connecting Uganda, Rwanda, Burundi, and the Democratic Republic of the Congo to the seaport of Dar es Salaam (Figure 1). This corridor forms a crucial part of the regional transportation system in East and Eastern Central Africa, carrying the import and export of the five countries with a population of more ~300 million people (Ogola et al. 2015). Tanzania is planning a mega-infrastructure upgrade to their Central Corridor (Enns et al. 2022), including the construction of the world's longest electrically heated crude oil pipeline (1443-km East African Crude Oil Pipeline [EACOP]), which will cross Murchison Falls National Park, home to about half of world's critically endangered Rothchild giraffe. The largest and most ambitious development project in the EAC is the Lamu Port, South Sudan, Ethiopia Transport (LAPSSET) Corridor Program that links Kenya, Ethiopia, and South Sudan (Brown 2015). LAPSSET Corridor plans contain seven mega-infrastructure projects: a new port, interregional highways, crude and product oil pipelines, inter-regional SGR lines, three international airports, and three resort cities (Figure 1).

These mega-infrastructure projects already traverse or are slated to traverse protected areas that are critically important habitats for multiple megaherbivore populations, creating an extraordinary wildlife conservation challenge. This challenge occurs because megaherbivores need a lot of space and mega-infrastructure projects result in strong and extensive environmental impacts that require large-scale mitigation. Some East African Savanna elephants have home ranges of >10,000 km^2, depending on habitat conditions (Ngene et al. 2017), which can span multiple mega-infrastructure projects. The EAC has identified 10 main corridors with a total length of about 15,000 km, named the East Africa Mega-Infrastructural Network (Figure 1). These roads, railways, electric lines, pipelines, and ferry routes are of strategic importance to multiple dimensions of society and development in the EAC, and their implementation is a likely matter of when, not if, they will happen. Without proper mitigation, these projects can create permanent barriers to megaherbivore movements, splitting and isolating populations, which can affect genetic connectivity, fitness, and viability (Hyvarinen et al. 2021; Lala et al. 2022). Now is a pivotal time to address how these projects can minimize negative impacts on biodiversity, especially megaherbivore populations that are globally unique and range from critical to vulnerable species status.

Recent conservation efforts amid development in Kenya provide a blueprint for conserving megaherbivores where mega-infrastructure projects traverse protected areas, such as national parks. Where the SGR in Kenya traverses ~165 km alongside and through Tsavo National Parks, it was designed with 41 crossings (eight bridges, six underpasses, and 27 culverts) to allow movement of wildlife populations, unlike the meter-gauge railway. The crossings include bridges that are between 20- and 1960-m long/wide and 4–12 m in height; underpasses between 60- and 70-m long/wide and 5.5–7 m in height; and culverts between 2- and 6.8-m long/wide and 2.4–5.5 m in height (Figure 2). The SGR was also elevated 18 m above the ground across the entire 6-km stretch where it crosses Nairobi National Park (Figure 2). Collectively, these crossings safeguard migration routes and population connectivity not only for megaherbivores but also for at least 33 species of medium to large mammals (adult weights >2 kg; Lala et al. 2022). Directive, strategic fencing to guide animals on where to traverse the SGR and highway was also key and important to reducing road and rail kill (Lala et al. 2022; Lala et al. 2021). First-of-their-kind monitoring efforts with GPS tracking collars (e.g., Okita-Ouma et al. 2021) have established that these conservation measures are proving successful at maintaining vital population connectivity for megaherbivores (Okita-Ouma et al. 2021; Koskei et al. 2022). Other large-scale, international mitigation efforts can also inform mega-infrastructure planning, such as India's recent success in building a 37-km elevated stretch of national highway with guide walls and nine underpasses of 50–750 m width, strategically placed to preserve tiger (*Panthera* spp.) and Asiatic megaherbivore movement routes and population connectivity (Habib et al. 2020).

Kenya's success in mitigating mega-infrastructure impacts on megaherbivores is key to informed development planning in the EAC. New road and SGR construction, in particular, can learn a great deal from Kenya's recent science on the use of crossings (Okita-Ouma et al. 2021; Koskei et al. 2022; Lala et al. 2022). While future challenges will arise and further mitigation efforts are a reasonable expectation (e.g., discouraging settlement and livestock congregation near wildlife passageways; Koskei et al. 2022), mitigative measures that include animal passageways (under or over), strategic fencing or guide walls, and science-based monitoring before and after implementation are needed because retrospective mitigation measures are likely to be cost-prohibitive.

There are opportunities to specifically incorporate megaherbivore conservation in EAC development planning. The Treaty for the Establishment of the EAC (Article 114) provides the mandate for the sustainable use of natural resources and requires EAC member countries to develop a "policy for the conservation and sustainable utilization of wildlife" (Article 116). The recent finalization of the EAC's Wildlife Conservation and Management Policy identifies infrastructure development as a priority policy issue and considers the establishment of a "wildlife sector coordinating unit" to have primary responsibility for regional wildlife policy. Establishment of a wildlife sector coordinating unit for the EAC is a must to best conserve megaherbivores amid mega-infrastructure development in East Africa. Such an

FIGURE 1 | Multiple existing and planned mega-infrastructure projects in the East African Community cross wildlife protection areas that contain important populations of megaherbivores (elephant [*Loxodonta* sp.], rhinoceros [*Diceros* spp., *Ceratotherium* spp.], hippopotamus [*Hippopotamus amphibius*], and giraffe [*Giraffa* spp.]). The LAPPSET (Lamu Port, South Sudan, Ethiopia Transport Corridor; red line) Program is a proposed multinational project to link Ethiopia, Kenya, and South Sudan. Standard-gauge railways (SGRs) are replacing meter-gauge railways regionally. See text for further details. Map credit: Grace Waiguchu.

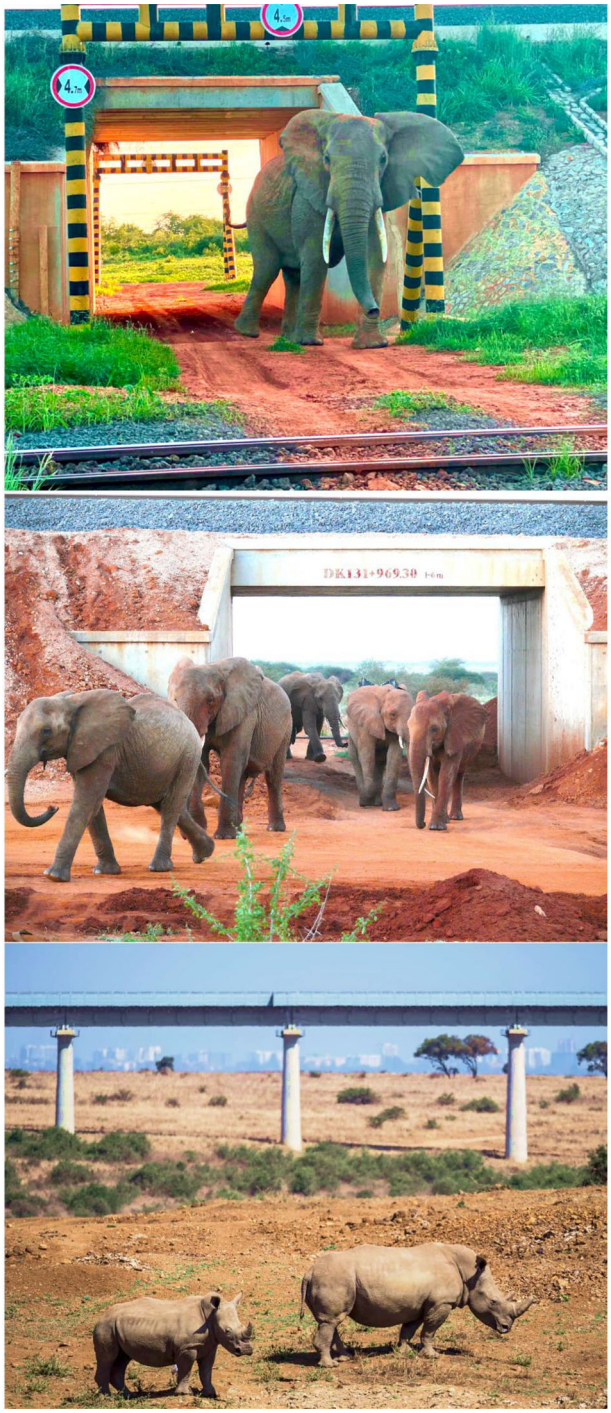

FIGURE 2 | Conservation efforts amid recent standard-gauge railway (SGR) development in Kenya include mitigating measures to conserve megaherbivores where mega-infrastructure projects traverse protected areas. Where the SGR in Kenya traverses ~165 km alongside and through Tsavo National Parks, it was designed with 41 underpasses of various sizes for megaherbivores (top and middle panel) to allow movement of wildlife populations. The SGR was also elevated 18 m above the ground across the entire 6-km stretch where it crosses Nairobi National Park (bottom panel). See text for further details. Photo credits: top, Richard Moller; middle, Simon Trevor; bottom, Pryia Bowry Sikand.

EAC coordinating unit should be a major priority in order to then implement the multiple approaches required to address wicked conservation problems. An EAC coordinating unit could establish that assessing, collecting, and synthesizing regional megaherbivore movement data to determine migration corridors and road/rail-kill hotspots should be a requisite part of the mega-infrastructure planning process (Lala et al. 2022; Lala et al. 2021). A wildlife sector coordinating unit in the EAC is also needed to help lead and contribute to multisector decision-making to enable management to span administrative boundaries, assess markets that incorporate natural capital, engage diverse stakeholders, and address environmental justice issues that accompany biodiversity conservation in the face of mega-infrastructure projects. Such a unit would be well positioned in the EAC to work incrementally in order to guard against the pitfalls of tame solutions and inaction from overwhelming complexity found in wicked conservation problems (DeFries and Nagendra 2017). Such a unit would also align with existing international frameworks of the EAC, such as the United Nations Environment Assembly's resolution on sustainable and resilient infrastructure.

Establishing an EAC wildlife sector coordinating unit will also support the national development plans of EAC countries (e.g., Tanzania's Vision 2025, Kenya's Vision 2030, Uganda's Vision 2040, Rwanda's Vision 2050), which are transformational aspirations to achieve middle-income status and provide economic prosperity and a high-quality life to all citizens. This coordinating unit could also further international commitments, such as the Convention on Biological Diversity and the Convention on Migratory Species, underscoring the unit's broader aim and significance. International support of these visions and aims should aid the formation of a wildlife sector coordinating unit in the EAC and include explicit measures to help address the wicked problem of conserving the regional asset and global treasure that megaherbivore populations constitute in the face of justified development (Bouraima et al. 2023; Bignoli et al. 2024).

Data Availability Statement

No original data were included in this perspective article. All data referenced are publically available through peer reviewed literature that is cited.

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