Exploring implications of elephant movements between land use types in a semi-arid savannah landscape

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Abstract

While the numbers and distribution of African savannah elephants (*Loxodonta africana*) have declined in many African range States, they have been steadily increasing in much of southern Africa. In Namibia's arid north-west, elephants are expanding beyond Protected areas (PA) into multiple types of land use, leading to socio-economic implications, both positive and negative. Our study aimed to quantify cross-land use movements and fence breaches and to explore the institutional, legislative and policy implications of fencing, as well as a new conservation paradigm for the area. We used satellite movements of eight collared elephant herds in multiple types of land use to the south and west of Etosha National Park for one year. Of these herds, seven had home ranges spanning multiple PA/communal/commercial landscapes, often crossing fences with management or disease significance. The implications of the movements between land uses are assessed in the context of relevant policy regarding management and economics. We conclude that despite challenges to livestock disease control and fencing damage, the expansion of elephant range has resulted in economic benefits to landowners and communal conservancies through tourism and possible consumptive use opportunities, as well as an improvement in general wildlife conservation practices in the area. Regardless of these benefits and the growing interest among rural residents in supporting the establishment of elephant corridors and the removal of fences, Namibia's legal and policy framework creates numerous implications for landowners and managers when considering fence breaches by elephants. We conclude with recommendations for holistic situational analysis of policy, law and practice and the consideration of amendments to outdated fencing requirements, thereby unlocking the economic and conservation benefits of elephant range expansion in the area.

Résumé

Alors que le nombre d'éléphants de savane (*Loxodonta africana*) et leur distribution géographique ont décliné dans la plupart des pays africains de l'aire de répartition de cette espèce, une augmentation régulière est constatée dans presque toute l'Afrique australe. Dans la région aride du nord-ouest de la Namibie, les populations d'éléphants se déploient au-delà des zones protégées, sur des espaces aux usages multiples, avec des implications socioéconomiques positives comme négatives. Notre étude a pour objectif de quantifier les

mouvements liés à cette utilisation croisée des terres ainsi que la fréquence des incidents de brèches dans les clôtures, et d'explorer les conséquences institutionnelles, législatives et politiques de la mise en place de telles clôtures. Un nouveau paradigme en ce qui concerne la conservation dans cette région est également examiné. Nous avons analysé pendant un an les déplacements de huit troupeaux d'éléphants munis d'un collier GPS sur des terres aux multiples usages se trouvant au sud et à l'ouest du parc national d'Etosha. Sept des huit hardes présentaient des domaines vitaux qui s'étendent sur plusieurs zones protégées, communales ou commerciales et qui traversent fréquemment des clôtures, avec des conséquences en termes de gestion et de transmission de maladies. Les implications de ces mouvements sont évaluées dans un contexte de politiques pertinentes au regard de la gestion et de l'économie. Nos conclusions montrent que, malgré les défis relatifs au contrôle des maladies du bétail et aux dommages infligés aux clôtures, l'expansion de l'aire de répartition de l'éléphant a contribué au développement d'avantages économiques pour les propriétaires fonciers et les réserves grâce au tourisme, aux potentielles opportunités de consommation, ainsi qu'à l'amélioration des pratiques générales de conservation dans la région. En dépit de ces bénéfices et de l'intérêt grandissant des habitants des territoires ruraux pour la création de corridors et la suppression des clôtures, le cadre juridique et politique de la Namibie contient de nombreuses implications pour les propriétaires terriens et les gestionnaires des zones protégées lorsqu'il s'agit d'examiner les destructions de clôtures par les éléphants. Nous concluons notre article par des recommandations en faveur d'une analyse situationnelle et holistique de la politique, de la loi et de la pratique, et d'un examen des amendements comportant des exigences obsolètes en matière de clôtures. Ces actions permettraient de débloquer les bénéfices de la conservation ainsi que les avantages économiques associés à l'expansion de l'aire de répartition des éléphants dans la région.

Introduction

It is well-known in ecology that the main strategy for the survival of large mammals in arid landscapes is movement (Bailey 2004; Wato et al. 2018). Herbivores disperse to find growing vegetation, followed by carnivores seeking migrating prey. In southern Africa, impressive migration of large springbok (*Antidorcas marsupialis*) herds was regularly documented in the 19th and 20th centuries, and John Skinner was convinced that fences would not have stopped the movement of these large herds (Skinner 1993). Rinderpest and breech-loading rifles, together with habitat fragmentation, largely laid waste to the herds and their ancestral migration. Humans have used a similar strategy of regular movement in arid areas, and even today the Ovahimba pastoralists outwit the unpredictable droughts of northern Namibia and southern Angola by following scattered rain-fed grasslands (Gibson 1977). African Savannah elephants (*Loxodonta africana*) are well known for being migratory across much of their range (and, unsurprisingly the desert-adapted Namibian north-west elephants, the subject of this study, are no exception (Leggett 2006, 2010; Leggett et al. 2003).

Namibia's elephant population is currently estimated at around 24,000 with a growth rate of 5.4% (between 4.20% and 6.53%) over the past 25 years (Craig et al. 2021). There are four main population groups: i) the Etosha National Park (NP); ii) Mangetti, northern Kavango; Khaudum/Nyae-Naye; iii) Zambezi; and iv) north-west (Fig. 1). The north-west population inhabits areas entirely outside of national PAs, spanning communal conservancies and commercial farmland in the Kunene and Erongo regions (Craig et al. 2021; Viljoen 1987) (Fig.1). With a growth rate of 3.86% (between -0.08% and 7.95%), this population has been expanding its distribution into commercial farmland in the Kunene region to the south and west of Etosha NP, resulting in extensive human-elephant conflict (HEC) (Hauptfleisch et al. 2024; Luetkemeier et al. 2023).

This expanded distribution has resulted in elephants moving across different land use systems in the Kunene region. The resultant conflict between landowners, farmers and elephants surrounding Etosha NP as well as the contiguous zones between communal and freehold land has been well documented (Luetkemeier et al. 2023). To date, however, it seems that the movement ecology of the north-west elephants has been studied in isolation in communal conservancies (Leggett 2010) and Etosha NP (De Beer et al. 2006; Lindeque and Lindeque 1991).

This study presents novel findings quantifying and exploring some of the potential implications of

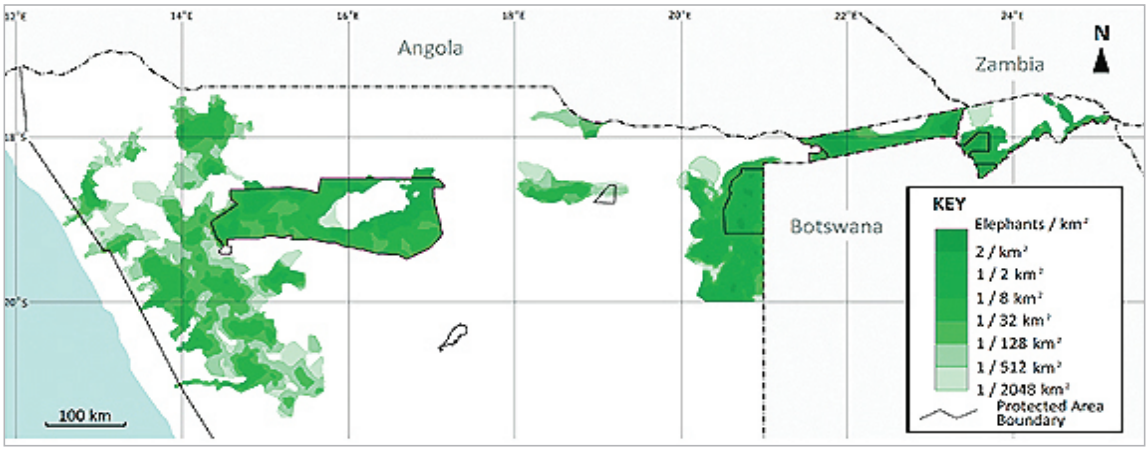

Figure 1. Elephant Distribution and density in Namibia showing both the Etosha and north-west populations in the west of the country (Craig et al. 2021).

elephant movement in different land use systems. Subsequently, the study aims to:

1. analyse the movements of eight satellite-collared adult female elephants in separate breeding herds in southern Etosha and the adjacent Kunene region (freehold and communal land) to quantify the extent of cross-land use movement as part of their survival strategy; and
2. explore the possible legislative and policy implications of this multiple land use movement.

The communal and free-hold agricultural land of the south-west of Etosha NP and Kunene (Fig. 2) is the ideal study area for this type of research, as wildlife movement and associated ecosystem services have been recorded and all rural land use systems of Namibia are represented.

Study area

The diverse land use and management context of the Kunene region and south-western Etosha that covers more than 30,000 km^2 defines the study area (Table 1, Fig.2). This region provides an ideal opportunity to compare the ecological, economic and social linkages within and between each land use type accommodating wildlife, and elephants in particular. This includes Ehirovipuka, Orupupa, Omatendeka, Huab and Audi and Khoadi–Hôas Communal Conservancies, Etosha NP (over 22,000 km^2), the Palmwag Government Tourism Concession area, Etosha Heights Private Reserve (EHPR) (a larger fenced area of 500 km^2) and individually fenced freehold cattle and wildlife farms with an average size of +/- 50 km^2 each. HEC has been reported widely across the area, with studies suggesting that it is increasing (Luetkemeier et al. 2023).

The area is considered hyper-arid with an average annual rainfall below 250 mm and is prone to frequent severe droughts (Mendelsohn et al. 2022). Average maximum temperatures are between 32 and 36^o C. Rainfall and surface water availability are a key driver of wildlife distribution and movement.

The landscape also includes a unique and significant barrier to wildlife movement, namely the Veterinary Cordon Fence (VCF). The VCF stretches from west to east through the country (red line in Fig. 2) and runs along the southern boundary of Etosha NP. It was constructed in the 1960s after the foot and mouth disease (FMD) outbreaks in northern Namibia. According to the Animal Health Act Regulations (GRN 2018), the area south of the cordon fence today is declared free of contagious bovine pleuropneumonia (CBPP) and FMD, the latter being a highly infectious disease that can be transmitted from wildlife to livestock and vice versa (Gadd 2012). FMD is a highly infectious, high-morbidity low-mortality disease, leading to severe reductions in livestock production. For example: the 2001 outbreak in the United Kingdom resulted in the need to cull over six million animals (Davies 2002). CBPP is both high morbidity and high mortality and is estimated to cause losses of € 44.8 million annually (Tambi et al. 2006). Only beef originating from this area south of the fence is accredited for import to

Table 2. Characteristics of different land use units with potential benefits from wildlife utilization.

Land use system	Tenure type	Livelihood commodities	Management of wildlife	Benefits from wildlife
National Park	Government-owned, proclaimed national park	Wildlife only	Extensive passive management and fortress conservation	National reputational benefits in protecting critically endangered species, tourism, source of breeding stocks for other parks and communal conservancies, wildlife research
Government Tourism Concession	Government land under lease to commercial tourism concessionaires	Wildlife and landscapes	Managed by the regional MEFT office	Tourism and occasional trophy hunting
Private nature reserve	Private ownership of multiple farms amalgamated without internal fencing. Private concessions for tourism and/or hunting with tourism or hunting operators. No formal proclamation	Tourism and hunting (wildlife only)	Privately managed, consumptive use of wildlife is regulated by government through the Nature Conservation Ordinance 4 of 1975 (GRN 1975)	Exclusive 'high-end' ecotourism, occasional hunt for staff food rations, possible trophy hunting in isolated instances
Commercial farm	Private ownership by an individual or a closed corporation	Mostly mixed wildlife and livestock.	Privately managed, consumptive use of wildlife is regulated by government through the Nature Conservation Ordinance 4 of 1975 (GRN 1975)	Trophy hunting, commercial meat hunting, products from wildlife skins
Communal conservancy	Owned by government but managed by an elected conservancy committee as mandated by the Nature Conservation Amendment Act of 1996 (Act 5 of 1996), (GRN 1996)	Mixed wildlife and livestock, and occasionally crop production for own use	Managed by conservancy committee with support from Namibian and INGOs. Tourism ventures are operated primarily through concessions by recognized tourism specialist companies	Tourism, trophy hunting, meat hunting, products from wildlife skins

the lucrative European Union market (Gadd 2012). Elephants in the landscape are known to consistently damage the VCF to access resources such as forage and water when driven by rainfall variability (Hauptfleisch 2022; Luetkemeier et al. 2023). This also enables the movement of many other animals in search of resources and the predators that follow them (Hauptfleisch et al. 2024). Therefore, the implications of the integrity of the fence in the context of elephant movements will also be discussed below.

Methodology

To achieve research goals (i) and (ii), this research applied the following animal movement tracking and literature review methods.

Tracking of elephant movements

Hourly GPS positions of eight female elephants in separate herds during the time period from 1 April 2022 to 31 March 2023. Two elephants were collared specifically for this study, while we also used data from

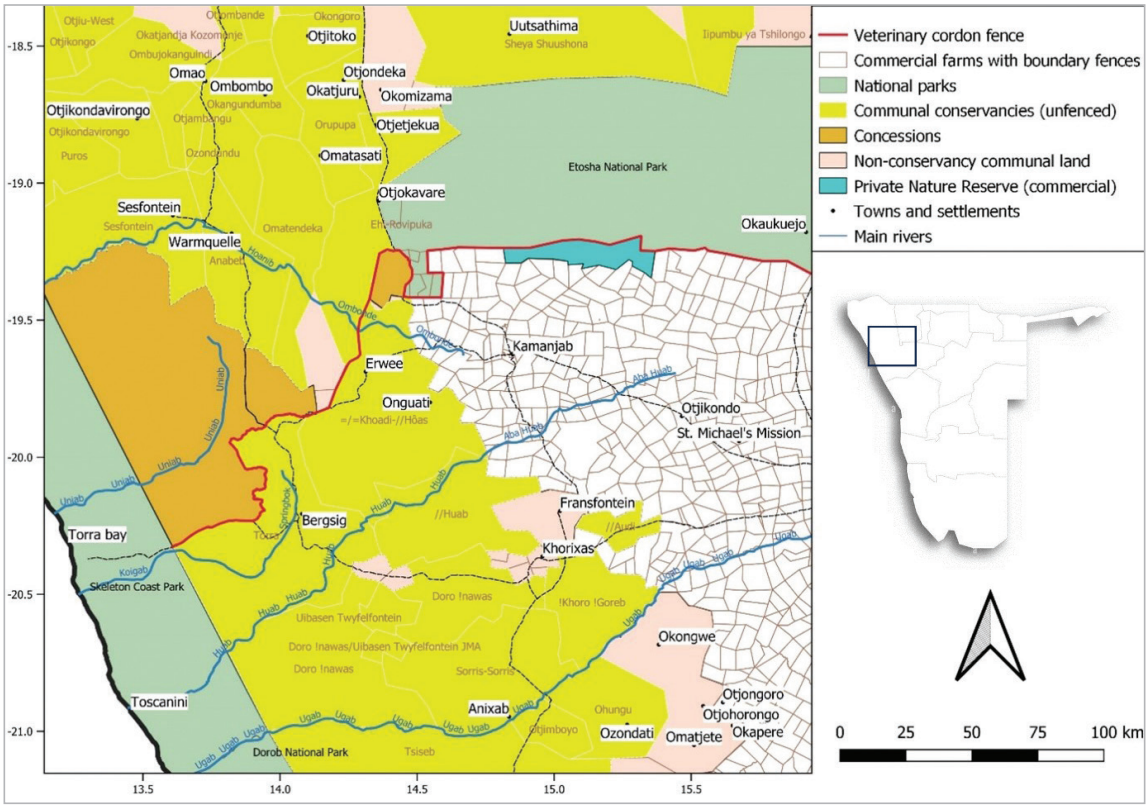

Figure 2. Etosha West and South Landscape study area.

six other elephants collared for other reasons, but within the same timeframe. No elephant was collared less than one month before the first data points considered, to prevent data from being biased by the animal's response to capture.

The Quantum Geographic Information System (QGIS) 2.18 was used for spatial analysis. The AniMove plugin and its Point-to-Path, Kernel Density Estimation, and Minimum Convex Polygon applications were used to determine the movement ecology characteristics of each study animal over the 12-month period. The System for Automated Geoscientific Analyses (SAGA) Intersection tool was used to determine how many times the animals crossed selected boundaries.

Legislative and policy review

This study aims to better understand elephant movements and their implications. Crossing boundaries has a physical dimension, as well as land use policy and legislative dimensions. To

Table 1. Study animals

Collar ID	Sex	Collared by/ information from:	Frequency of location recording
Fransi	Female	Existing data	Hourly
Iris	Female	Existing data	Hourly
4794	Female	Authors	Hourly
4792	Female	Existing data	Hourly
4793	Female	Existing data	Hourly
4788	Female	Existing data	Hourly
4962	Female	Existing data	Hourly
Sara	Female	Authors	Hourly

identify these, an analysis of relevant legislation relating to wildlife management or movement was conducted in the different land use and management units in the study area.

Open-source spatial data from the Namibia Statistics Agency (NSA) as published in the Atlas of Namibia (Mendelsohn et al. 2022) were used to identify the geographic distribution of land use systems, PAs and the VCF. From there, different types of land use and land tenure, livelihood commodities, management regime, and potential benefits were identified. Relevant legislative and policy provisions were analysed to inform the potential socio-economic implications of movements across the differing land use systems. These included the Nature Conservation Ordinance (GRN 1975), Fencing Proclamation (Namibia, 1921), Animal Health Act (GRN 2011), the National Elephant Conservation and Management Plan and the Revised National Policy on Human Wildlife Conflict Management 2018–2027.

Results

The results are separated into two outcomes, namely the spatial movement of elephants across the land use types (research aim i) and a comparative understanding of different land use type characteristics. Subsequently, Table 2 summarizes the different types of land use and tenure based on wildlife, as well as their relative livelihood, management, and potential benefit characteristics, while Fig.3 shows the characteristics of elephant movement.

All eight collared elephants crossed between different types of land use during the study period, and none of the elephants moved exclusively within a communal, concession area, or national park (Fig. 3, Table 3). Only elephant 4788 utilized a single land use type, this being commercial farmland. Interestingly, this elephant had a considerably smaller home range of 455.53 km^2 than the mean of 1,621.86 km^2 for all the elephants. Fransi and Iris used three types of land use while the other animals used two. There were a total of 1,300 fence breaches during the 12-month study period (Table 4), with 719 between individual commercial

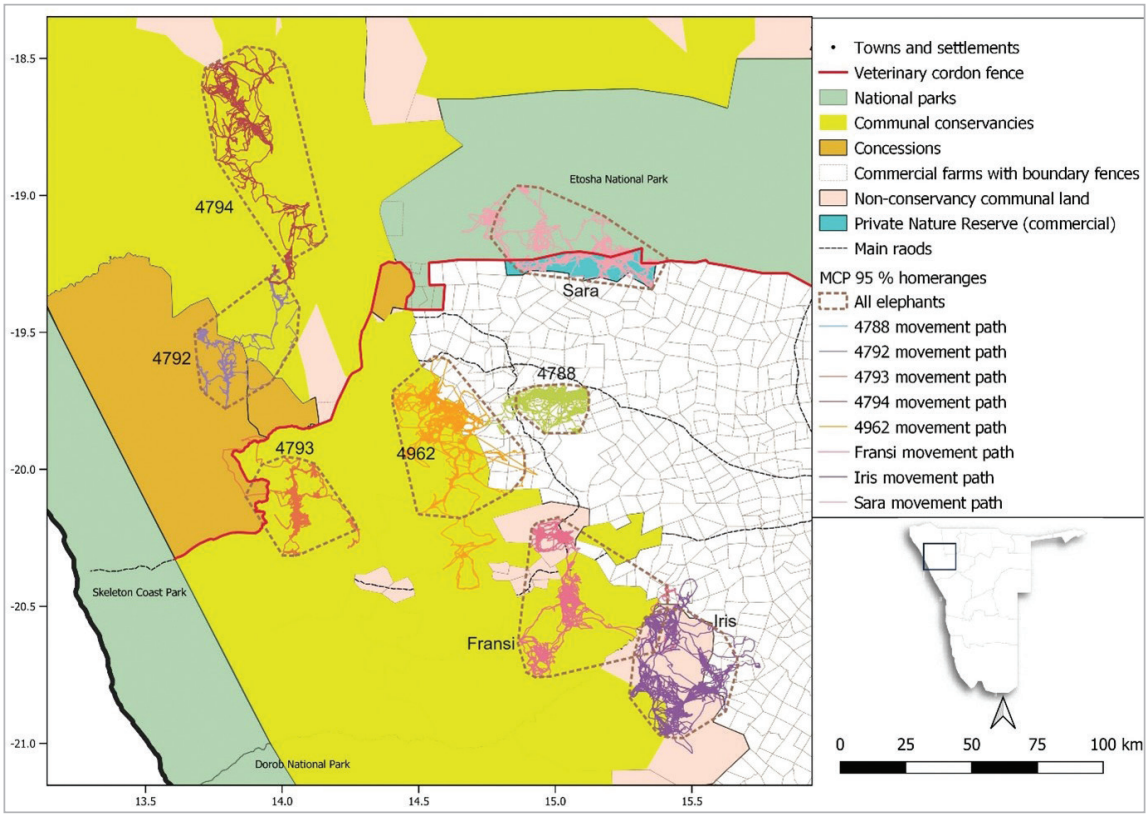

Figure 3. Home ranges and movement paths for eight female elephants during the period April 2022 to March 2023.

Table 3. The extent of total home ranges (MCP 95%) in different types of land tenure.

Elephant	Total home range size (MCP 95) km²	Portion of home range on communal conservancy in km² (and % of total home range in brackets)	Portion of home range on non-conservancy communal land in km² (and % of total home range in brackets)	Portion of home range in national park in km² (and % of total home range in brackets)	Portion of home range on commercial farms in km² (and % of the total home range in brackets)	Portion of home range on government concessions in km² (and % of total home range in brackets)
Fransi	2,615.79	1,962.71 (75.03%)	372.04 (34.23%)		281.04 (10.74%)	
Iris	1,607.56	164.42 (10.23%)	1,183.1 (73.60%)		260.04 (16.17%)	
4794	2,494.98	2,477.46 (99.30%)	17.52 (0.70%)			
4792	1,370.02	777.92 (56.78%)				592.10 (43.22%)
4793	1,084.12	1,007.13 (92.90%)				76.99 (7.10%)
4788	455.53				455.53 (100%)	
4962	2,178.94	1,471.31 (67.52%)			707.63 (32.48%)	
Sara	1,731.98			1,167.92 (67.43%)	564.06 (32.57%)	

Table 4: Number of times fence lines were crossed by eight elephant females between April 2022 and March 2023.

Elephant	Number of fence line crosses between Etosha NP and a commercial Farm	Number of times VCF was crossed	Number of fence line crosses between individual commercial farms	Number of fence line crosses between communal and commercial land
Fransi	0	0	13	5
Iris	0	0	57	93
4794	0	0	0	0
4792	0	0	0	0
4793	0	3	0	0
4788	0	0	608	0
4962	0	0	41	192
Sara	144	144	0	0
TOTAL	**144**	**147**	**719**	**290**

farms. The cordon fence was breached 147 times. Six of the eight adult females crossed fences, while the other two crossed boundaries that are geographically demarcated (between individual communal conservancies and between conservancies and unfenced government tourism concessions. Elephant 4788 was exclusively resident in a commercial farming area, continually breaching fences (or accessing farmland through the same damaged fence), with the second most breaches between communal/commercial boundary fences by three of the elephants. Sara was the only animal collared in the vicinity of Etosha NP and crossed the park boundary 144 times. This boundary also forms part of the VCF, and all but three of all VCF fence line crosses were by this elephant.

Discussion

The results indicate that elephants regularly move between multiple types of land use with home ranges of seven of the eight herds stretching across different types of land use and management. Often, elephants damage fences in their quest to access certain areas, indicating that drivers to find resources in this arid landscape outweigh potential threats from hostile residents and physical barriers. Growing populations of elephants compressed within PAs may also be driving more elephants into neighbouring non-conservation land (Craig et al. 2021). This study did not investigate these drivers but recognizes the importance for further study. It is well understood that the ability to move and track forage and water availability is a vital adaptation for elephants in arid parts of Africa where rainfall is erratic and patchy (uniquely Namibia and Mali) (Hauptfleisch et al. 2024; Wall et al. 2013). The drivers of the movements of the elephants considered in this study are important factors for future research on these elephants.

The sizes of the home ranges of the elephants were variable (455–2,615 km^2) as expected for an area with variable and erratic rainfall. The home ranges were mostly smaller than those found by Leggett (2006), whose work was in the communal land of the same region but comparable to Viljoen (1987). The elephant that crossed fence lines the most (4788) also had a considerably smaller home range than the others. This elephant is also likely to have encountered the most hostile landowners in the study area, being part of the Kamanjab 'problem' population. It would also have encountered the most fences since the farms are not only externally fenced, but often also internally fenced. Although elephants can easily breach fences, their movements are still hindered, especially since some fencing is electrified. There does not appear to be any relationship between the size of the home range of any of the other study animals and their use of specific land use areas.

The potential implications of cross-fence multi-land use movements

The implications of elephant movement policy were categorized based on the movement data shown in Fig.3 and Tables 3 and 4.

Movement between commercial farms

Besides possible tourism benefits, from a wildlife utilization perspective the movements of 'Fransi', 'Iris', '4788' and '4962' between commercial farms has potentially negative implications predominantly in terms of the Nature Conservation Ordinance (GRN 1975). These include the potential loss of elephants and other wildlife for utilitarian consumption (a 'resource') in terms of the requirement for adequate fencing to hunt on a farm (See Section 26(4)(a)). The adequate enclosure of wildlife is required for proof of ownership (See section 29.) Furthermore, these animals can, depending on the circumstances, be declared problem or damage-causing animals in terms of the ordinance and will have to be destroyed or removed according to the guidance provided by the revised policy on HWC management (MEFT 2018) (see also sections 53 and 54 of the ordinance (GRN 1975)). Following fence breaches by elephants, other wildlife often follows. Hauptfleisch et al. (2024) reported the movement of more than 9,000 large mammals at three elephant breach locations over a month. These included lion (*Panthera leo*), cheetah (*Acinonyx jubatus*), leopard (*Panthera pardus*) and nine species of wild ungulates. This could have further socio-economic implications for landowners, both as welcome resources but also negatively in terms of problem or damage causing animals. A philanthropic organization has taken advantage of the increased presence of elephants on commercial properties in the area represented by our study animal 4788; and has recently purchased three of the farms on which 4788 roams from cattle farmers who suffered conflict with the elephants. The intention is to provide sanctuary for elephants and connect movement corridors with neighbouring like-minded farmers and communal land to the west. This seems to indicate that the movement of elephants into commercial areas could affect landowners' decision to accommodate the elephants or sell their properties to individuals or organizations willing to incorporate wildlife into a diversified approach, together with farming practices. From an ecological perspective, the movements suggest that a single farming unit is too small to provide the resources and cater to the needs of elephants, making the consolidation of farms and establishment of corridors of even greater importance.

Movement between commercial and communal land

In terms of the movements between commercial and communal lands such as those depicted by Fransi, Iris, and 4962, the legal implications are similar to those discussed above except for the provisions of Section 24B of the ordinance, which grants the applicable conservancy committee the right on behalf of the community who resides on said communal land, to give effect to consumptive and non-consumptive use and sustainable management of wildlife in the area. Thus, elephants on communal land can be used as a resource following the ordinance prescripts and in line with management planning. Sustainable utilization of wildlife is strongly advocated in Namibia. The elephant management plan recognizes the important role that rural communities and communal conservancies play in elephant conservation while recognizing that such conservation success relies heavily on the benefits that communities can accrue from elephants in the form of consumptive and nonconsumptive uses.

Movement between Etosha NP and contiguous private land

Despite increased HEC between livestock farmers and elephants in the study area (Hauptfleisch et al. 2024; Luetkemeier et al. 2023), there has been a shift towards the incorporation of elephants and other wildlife into socio-economic activities. Of the 22 commercial farms that border Etosha NP in the south, only one, the Heellaas resettlement farm, does not have wildlife either for trophy hunting, hunting for meat or tourism. EHPR (blue in Fig. 3) has consolidated nine commercial farms and exclusively practices high-end tourism. Elephants are one of the top tourist attractions in the reserve. In tolerating fence breaches and maintaining conservation objectives similar to those subscribed by MEFT (for their national parks) the need to repair the fence between the Etosha NP and EHPR becomes less necessary. This has significant cost-saving implications for the Park which is responsible for maintaining a fence line of over 800 km on a limited budget. The above scenario is well illustrated by the movements of Sara, who moved across the Etosha NP and EHPR boundary a total of 144 times during the study period.

Movement across the Veterinary Cordon Fence (VCF)

The boundary between Etosha NP and private land to the south is also the VCF. Elephants in the landscape are known to consistently damage the VCF to access forage and water availability when driven by rainfall variability (Hauptfleisch 2022; Luetkemeier et al. 2023). This also enables the movement of many ungulates in search of resources, as well as the predators that follow them (Hauptfleisch et al. 2024). Despite the economic risk of reducing the integrity of the VCF and damage to farming infrastructure from cross-boundary movements, stakeholders in the landscape identified the elephants as a socio-economic opportunity in terms of their sustainable use and tourism value (Hauptfleisch 2024; Luetkemeier et al. 2021). This has already resulted in a shift from traditional commercial cattle ranching to tourism and trophy hunting across much of the landscape (Hauptfleisch 2024), as has been the case in other parts of southern Africa (Kreuter and Workman 1996). There are actors within the area (Pers. comms; Andre Nel, April 2023; Tinus Hansen, September 2024) who believe the southerly elephant movements can be a catalyst for wildlife movement corridors, expanding elephant and other wildlife ranges and connectivity across the landscape (Hauptfleisch 2022). Such corridors have been proposed as a solution in other parts of southern Africa (Songhurst et al. 2023).

The legal and socio-economic implications of this fence breach are numerous. Firstly, elephants crossing this fence become potential resources in accordance with provisions of the ordinance allowing for the trophy hunting of wildlife. The legal prescripts relating to problem or damage-causing animals also apply. The breach of the VCF has numerous negative implications for the disease-free status of commercial beef production south of the fence (GRN 2011). Despite the implications of the fence breach, the land-use system around EHPR is conducive to elephant movement, which it considers of potential non-consumptive tourist value.

The 147 breaches of the cordon fence that we identified (Table 4) provide an economic threat, but interestingly also an economic opportunity, which has been fully embraced by the landowners where the study animal Sara moves between. The crossing of the VCF creates several legal implications in terms of the Animal Health Act (GRN 2011), and the deceleration of the protected and quarantined areas separated by

the VCF (GRN 2018). Veterinary fences and strict controls allow commercial farmers to participate in lucrative international markets (McGahey 2011). In 2019, beef was exported to the value of approximately €44.8 million from Namibia to the European Union (Bennett and Rich 2022). However, the benefits and the long-term maintenance of this fence are increasingly under scrutiny among different interest groups: while the negative effects on wildlife ecology have long been observed (Martin 2005; Wall et al. 2013); the trade regulations set by the World Organization for Animal Health (OIE) implore the government to maintain the fence, which is frequently damaged by elephants and other wildlife. Interviews with local farmers in 2019 revealed their concerns about the dependency on the EU, as their business is controlled by the integrity of the anthropogenic fence. Considering the costs of maintaining the VCF, Scoones et al. (2010) suggest detachment from the fence-dependent strategy and instead apply another mechanism like commodity-based trade: setting the focus on an acceptable risk coming with the product to be traded. This may require seeking other international markets or lobbying the EU to amend strict disease control mechanisms. In this regard, certification was suggested to adapt to additional markets and allow more farmers to benefit. This strategy may be interesting for Namibia, whose vision is to also develop the livestock sector north of the VCF to integrate farmers into international markets (Meat Board of Namibia 2015).

This study could stimulate the debate around the question: *Should the fences be fixed?* For a commercial cattle farmer south of the VCF, the answer would undoubtedly be yes, but for the private nature reserve who has increased tourism value it is potentially no. A national study by the Ministry of Agriculture Water and Land Reform was recently commissioned to explore the possibility of removal of the VCF and its potential implications (New Era 2024). For conservationists (and trophy hunters), the expansion of elephant range onto private farmland is a rare and exciting occurrence, particularly since it is a catalyst for wildlife conservation and changes in land use tenure to accommodate wildlife. Where most elephant habitat across Africa is being lost or fragmented at an alarming rate (Chase and Griffin 2009) with a new approach attempted the movement of animals such as 4788 and 4962 onto areas they have not inhabited in recent times is of conservation value to the species, but at a cost to commercial livestock farmers. There is considerable cost to farmers when elephants damage water installations to access livestock watering holes and damage boundary and internal fencing designed to aid rotational grazing practices (Luetkemeier et al. 2023). Legislation currently favours fencing to control disease, as well as an animal containment tool to confirm ownership over wildlife or rights to their use. The National elephant Conservation and Management Plan (MEFT 2021) now advocates inter alia for considering removal of some fences in the wider Etosha ecosystem to facilitate the movement of elephants across the landscape and to cooperate with neighbours in PAs (MEFT 2021: 4 and 14).

Movement between communal conservancies

The situation where elephants move across communal conservancies, as depicted by the movement data in Fig.3, may have legal implications concerning which community has the right to utilize the elephants consumptively. Section 24A of the ordinance allows for the formation of communal conservancies and through Section 24A(4) for the consumptive and non-consumptive use and sustainable management of wildlife therein. Therefore, it follows that elephants within such areas are potential resources for the communities in whose conservancy they may be found. This is a valuable addition or alternative to subsistence livestock farming, which is becoming more marginal due to climate change. This also aligns with the visions of the elephant management plan which recognizes elephants as a potential resource for communities and conservation agencies and encourages sustainable use (MEFT 2021). Therefore, cooperative management of elephants and other wide-ranging species should be encouraged to determine use rights over an entire landscape and not an individual conservancy.

The elephant movement data used in this study were rudimentarily analysed to determine whether the elephants used multiple land uses and quantified their movements across fence lines. This provides a basis for the examination of possible policy implications. A follow-up study will further interrogate the spatial data to determine whether there are behavioural differences in different land uses or in the vicinity of fence lines compared to unrestricted areas. It will also look at

seasonal differences and investigate drivers of elephant movement such as water availability, density of human settlement and vegetation growth in response to rainfall.

Conclusions

This study used data from eight collared elephants in separate herds to show that there is extensive movement of elephants between different land uses in Namibia's Etosha West and South Landscape. Movement data show multiple breaches of fences, which, in addition to direct costs of repairs, may have negative legal and associated socio-economic implications. Despite this, the opening of the landscape through elephant fence breaches provides an opportunity for landscape-level conservation and ecotourism. To realize this potential, we highlight the following challenges and recommendations.

Aligning policy and legislative objectives across land use types: Implications of movements across land use types can be traced back to the level of alignment between land use objectives. Clearly, the implications of elephant movement across land use types with compatible tourism and conservation objectives (i.e. national parks, private nature reserves, communal conservancies) are more easily dealt with than less compatible land-use objectives such as commercial farming. To better align land use aims, an emphasis is needed on promoting certain objectives. These incentives could include cooperative eco-tourism opportunities, elephant movement servitudes, or wildlife credit schemes, but should ultimately support landowner expectations and the general utility of the land, whether owned by the state, communities, or individuals.

Providing for discretion and flexibility in the enforcement of policy and legislation across land-use types: The enforcement of legislation typically happens on a case-by-case basis as stipulated in law. However, the movement scenarios discussed in this paper highlight the high level of potential complexities for law enforcement related to the requirements of policy and legislation mentioned previously. Because of these complexities, enforcement requires higher levels of discretionary thinking and flexibility than what is currently provided for in the system taking advantage of a more open and connected landscape is also a means of decreasing pressure on enforcement systems, which are notoriously expensive and slow to respond to innovative opportunities.

Innovative fencing technologies and solutions: A notable obstacle to allowing for wildlife movements at landscape scale is the requirement for fencing of individual farm units to be permitted in order to utilize their wildlife resources and for livestock disease control. It is therefore recommended that revisions of these outdated regulations consider case-by-case proposals for fenceless landscape-level wildlife corridors across land units and between parks, conservancies, and wildlife areas if these land custodians or owners are willing and in agreement. However, the complete removal of fences will not be possible for certain corridor areas, especially when commercial farmland is concerned, and therefore innovative technological fencing designs and solutions should be considered and supported. Much thinking and technological development exists to selectively manipulate of animal movements through 'smart fencing' systems e.g. use of artificial intelligence to trigger alerts or opening of gates. Therefore, the complete liberation of the elephant movement will strongly depend on the development and implementation of such technologies. New fencing technology will require a rethink of current legal fencing requirements and specifications.

Although a limiting factor of this study is the small sample size, this paper provides a first attempt to highlight the implications of elephant movements across multiple tenures of land use for a particular region of Namibia. We trust that the results will have wider relevance in southern Africa and contribute to broader thinking about animal movement in complex land use systems. A better understanding of elephant movement in relation to land use policy and legislation has been identified as a key risk to conservation (Alberts et al. 2022; Retief et al. 2022; 2023) and could become an increasingly important consideration in effective wildlife management and conservation, not only in Namibia, but also across African elephant range States where space for wildlife is diminishing. Finally, we recommend more detailed analyses of elephant seasonal movements in relation to their behaviour and home range characteristics on different land uses, and the environmental factors/ecological drivers of their movements, for future study.

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