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Co-management brings hope for effective biodiversity conservation and socio-economic development in Vwaza Marsh Wildlife Reserve in Malawi

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Co-management has been widely promoted in protected area management on the premise that it may simultaneously enhance biodiversity conservation outcomes and improve livelihoods of the park-border communities. However, the success of this management approach remains a growing debate raising the question of its effectiveness. To contribute to this debate, we used local community perceptions and secondary ecological data to assess the extent to which co-management has effectively contributed to biodiversity conservation and socio-economic development outcomes in the Vwaza Marsh Wildlife Reserve. Face-to-face individual interviews using a semi-structured questionnaire were used to collect data on the perceptions of co-management from 160 purposively selected heads of households. A desk study was used to collect data on trends in animal populations, animal mortality, and prohibited activities including incidences of poaching for the past 30 years (pre-and post-introduction of co-management). Results showed that local communities have positive perceptions of the conservation work in the Vwaza Marsh Wildlife Reserve. Further, there was an improved people-park relationship and a recovery of animal populations in the reserve after the introduction of co-management. These findings point to the success of co-management in the area. However, misunderstandings over revenue sharing were still a thorny issue, somehow creating mistrust between parties. We concluded that while it may still be early to achieve more demonstrable conservation outcomes, co-management appears to bring hope for effective

biodiversity conservation and socio-economic development in the Vwaza Marsh Wildlife Reserve. Participatory evaluation of co-management involving key stakeholders is recommended in the Vwaza Marsh Wildlife Reserve based on the findings of this study and lessons learnt over the years.

KEYWORDS

community perceptions, collaborative management, protected area management, community-based natural resources management, rural livelihood

Introduction

Biodiversity conservation in protected areas (PAs) is evolving from coercive to more people-centred approaches. Since the 1980s, there has been a growing recognition of the critical role of local communities in the management of PAs, with many studies emphasising the need for more inclusive and people-oriented approaches (Wells and McShane, 2004; Dawson et al., 2021; Gatiso et al., 2022; Ma et al., 2022). This has been a reaction to the failures of exclusionary conservation approaches to achieve conservation, economic, and development goals of PAs (Berkes, 2004; Watson et al., 2014). Indeed, PA managers, especially in developing countries where socio-economic and cultural factors predispose some people to over-rely on the immediate environment to meet their daily livelihood needs (Shackleton and de Vos, 2022; Zhang et al., 2022), are continuously faced with the challenge of balancing multiple goals of PAs (McShane et al., 2011; Allendorf and Yang, 2013; Gidebo, 2022; Yousefpour et al., 2022).

The management challenges faced are in part emanating from the historical context of biodiversity conservation in PAs. For a long time, PA management has mostly been the sole responsibility of national governments, modelled on Yellowstone National Park, the first PA established in 1872 (Andrade and Rhodes, 2012) and based on values that have less regard for local people and their livelihoods (Andrade and Rhodes, 2012; Sarkki et al., 2015; Umar, 2018). The exclusion further meant the prohibition of local communities from accessing wildlife resources that have been supporting their very lives since time immemorial (Berkes, 2004; Berkes, 2009; Sarkki et al., 2015). Consequently, antagonism and conflicts between local communities and government agencies have not been uncommon. The consequences have been widespread rebellion, hostility, rule-breaking, and increased anthropogenic pressure in PAs such as poaching and deforestation (Anthony and Szabo, 2011; Spracklen et al., 2015; Gray et al., 2018; Geldmann et al., 2019; Matseketsa et al., 2019). This may essentially reduce the quality and quantity of ecosystem services provided by PAs to people, ultimately leading to the disruption of local livelihoods. These challenges, coupled with many mixed reports on the success of PAs (Leverington et al., 2010; Muhumuza and Balkwill, 2013; Watson et al., 2014; Oldekop et al., 2016; Singh et al., 2019; Robson et al., 2022), have continually put into question the effectiveness of PAs as conservation and development cornerstones (Anthony and Szabo, 2011).

Collaborative management or Co-management has been defined as the sharing of power and responsibility between government or state and local resource users (Berkes, 2009). In this governance and management system of natural resources, each party has roles and obligations, and is accountable to each other. It has been widely promoted on the premise that it may enhance biodiversity conservation outcomes while also serving the interests of social and economic development (Berkes, 2004; Berkes, 2009). It is believed that biodiversity conservation efforts would become more successful if communities that carry the burden of living with wildlife were involved in the conservation work and benefited from it (Berkes, 2004; Anthony, 2007). In this respect, Sub-Saharan Africa has been one of the experimental regions for co-management (Zulu, 2013; Umar, 2018). However, since its introduction, its effectiveness remains debatable and mixed results are reported in the literature on its success across different ecosystems (Fabricius and Collins, 2007; Campbell et al., 2013; Oldekop et al., 2016; Kabeer et al., 2018; Rahman, 2022). Moreover, both access and restrictions to wild resources seem to escalate extraction of prohibited resources, varying with socio-economic and cultural factors (Shova and Hubacek, 2011; Muhumuza and Balkwill, 2013). This suggests the need for context-specific evaluation of co-management as a conservation approach.

This study was aimed at evaluating the extent to which co-management has effectively contributed to biodiversity conservation and socio-economic development outcomes in the Vwaza Marsh Wildlife Reserve (VMWR) in Malawi. According to Pressey et al. (2021), conservation impact of a PA is the sum of avoided biodiversity loss and promoted recovery relative to outcomes without protection. We therefore examined the effectiveness of co-management on biodiversity conservation by quantifying changes in the abundance and mortality of animal species, and illegal activities (Sarkar et al., 2022), On the other hand, effectiveness on the socio-economic development outcomes was investigated by documenting the goods and services that local communities obtain from the reserve, and other perceived benefits including development projects attributable to co-management. The VMWR became one of the pilot sites for co-management in the early 2000s through a donor-funded project (Zulu, 2012) concomitant with the global changes in biodiversity conservation approaches. The Department of National Parks and Wildlife (DNPW) entered into a governance and management

working relationship with local communities bordering the VNWR to improve the conservation goals and human well-being in the area. However, as with other PAs (Muhumuza and Balkwill, 2013; Oldekop et al., 2016), limited evidence of the success of co-management since its introduction in Malawi partly undermines the upscaling of this management approach. Several previous studies have often used perceptions and attitudes of local communities bordering PAs as a proxy for evaluating the effectiveness of co-management (e.g., Bennett, 2016; Allendorf, 2020; Katswera et al., 2022; Rampheri et al., 2022) by way of focusing on the park-people relationships and benefits accrued to local communities.

It is widely recognised that attitudes and perceptions of the park-border community towards conservation work can provide insights into their behaviour, compliance with conservation regulations, willingness to participate, and acceptability of conservation management (Bennett, 2016; Katswera et al., 2022). As such, understanding these perceptions is crucial for developing successful, long-term conservation and management strategies (Ellwanger et al., 2015). Perceptions can also be used as a starting point for developing the park-people relationship which is crucial for local community commitment to effectively participate in conservation work (Vodouhê et al., 2010). For PAs where there has been a park management shift from a strictly state-controlled approach to a governance and management agreement with the bordering local communities such as the VMWR, local community perceptions may also help identify conservation conflicts that may inform conservation decision-making (Janssens et al., 2022). More importantly, perceptions may also aid in assessing the performance of conservation work and eventually help in the development of an adaptive co-management approach that could lead to improved conservation and development outcomes (Bennett, 2016; Abukari and Mwalyosi, 2020). It has further been suggested that quantifying perceptions and attitudes towards ecosystem conservation of local communities can help assess the success of current conservation goals and actions and inform future practices (Xu et al., 2022). Positive perceptions in this regard are indicative of a successful conservation approach (Bennett, 2016; Allendorf, 2020).

Already, community perceptions have been used to facilitate proper conservation in PAs (see Liu et al., 2010; Allendorf et al., 2012). However, rarely has a single study looked at both ecological and social data collected inside and outside PAs (but see Sarkar et al., 2022), thus undermining more conclusive evidence of what is working, what is not, and why (Pendleton et al., 2018). Moreover, although elements of co-management have been examined elsewhere in Malawi (Gordon, 2017), a systematic assessment of the perceptions and ecological conservation outcomes before or after the change in the management approach in the VMWR is opaque in the literature. Such information would be important to guide management decisions for the improvement of co-management in the VMWR. It has been suggested that local people's knowledge can have a valid relevance in PA management and could assist in developing effective conservation strategies, as well as in the overall improvement of local socio-ecological systems (Afriyie et al., 2021).

Previous studies in the VMWR that tackled elements of co-management and/or local community resource use include those that focused on spatial patterns of resource use and prohibited activities (McShane, 1990), resource use by communities based on permit records (O'Sullivan, 2019), and patterns of bushmeat hunting and consumption (van Velden et al., 2020). In this study, we used local community knowledge, perceptions, and secondary ecological data (animal population estimates and animal mortality) to assess the extent to which co-management has contributed to the effectiveness of biodiversity conservation and development outcomes in the VMWR. We made the following assumptions: (1) that co-management had provided local communities with increased access to resources important for improved livelihood in the VMWR (Muhumuza and Balkwill, 2013; Woodhouse et al., 2022); (2) that co-management had brought a positive perception of biodiversity conservation among local communities in the VMWR (Woodhouse et al., 2022); (3) that co-management had reduced extraction of prohibited resources in the VMWR (Woodhouse et al., 2022); (4) that co-management had provided local communities with a problem-solving platform to improve their quality of life (Berkes, 2009); and (5) that choices, knowledge, and perceptions of local communities of biodiversity conservation and sustainable use were influenced by their socio-demographic factors (age, gender, level of formal education, distance from the reserve boundary, and membership to a conservation institution) (Shibia, 2010; Muhumuza and Balkwill, 2013).

Materials and methods

Study site and context

Vwaza Marsh Wildlife Reserve (VMWR) is located at 33° 28' E and 11° 00' S, covering an area of about 986 km^2. The reserve is found in Rumphi District and lies on the watershed between Lake Malawi and the Luangwa valley, with the western part of its boundary forming the Malawi-Zambia border (Mgoola and Msiska, 2017) (Figure 1). The VMWR has an annual mean temperature range of 16 - 28°C; altitude varying from 1000 to 1660 m a.s.l, and a mean annual rainfall range of 700 - 1100 mm, often falling from November to April. Temperatures are lowest during the early dry season (May to August) and highest in the late dry season (September to November) (Mgoola and Msiska, 2017). The major characteristic features of the reserve including microhabitat types, and animal and plant communities are reported elsewhere (Engel et al., 2013; Mgoola and Msiska, 2017; Sichinga, 2019). The reserve contains the most extensive wetlands in the plateau area of Malawi and is bordered by a community that practices mixed farming of crops and livestock (McShane, 1990; Mgoola and Msiska, 2017). The human population density has grown from a mean density of about 28 persons/km^2 in 1990 (McShane, 1990) to about 63 persons/km^2 in 2020 (van Velden et al., 2020). The park-border community is mainly composed of the Tumbuka, Phoka, and Ngoni ethnic tribes, and are traditionally hunting tribes (van Velden et al., 2020). As with many other areas in

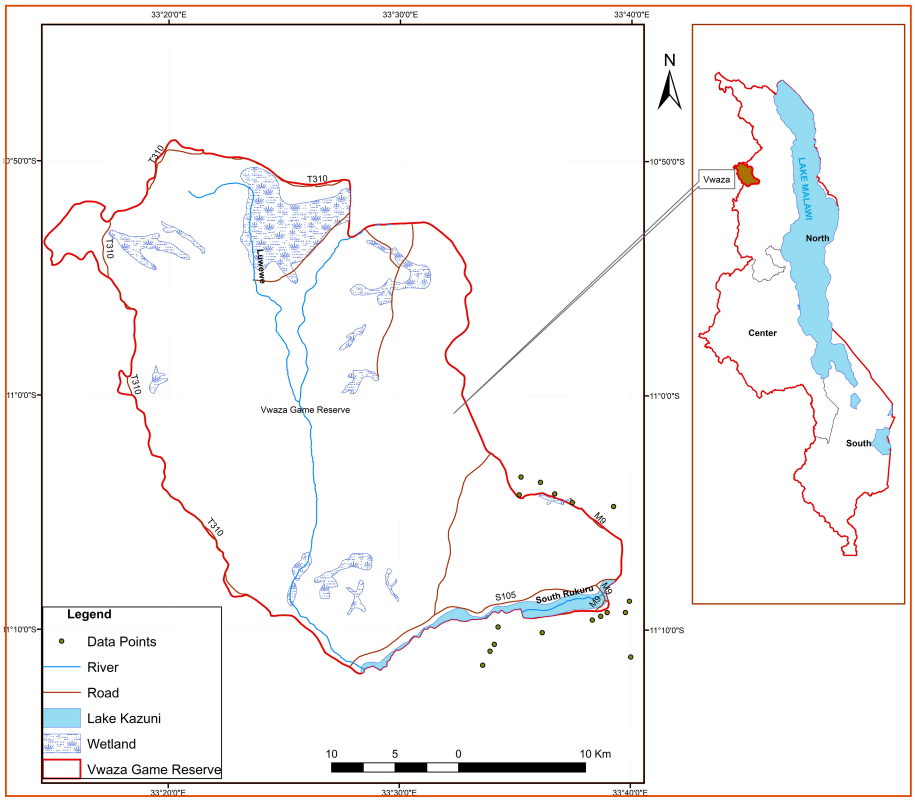

FIGURE 1
Map of the Vwaza Marsh Wildlife Reserve showing locations of study villages.

Malawi, poverty and food insecurity are some of the major challenges. According to the World Bank (Caruso and Sosa, 2022), nearly 73.5% of the population in Malawi lives on US$ 1.90 per day and about 2.3 million people (approx. 12% of the country's population) are perpetually food insecure.

The historical context of the VMWR is well elaborated by McShane (1990). Suffice it to say that efforts to protect the area began in 1941 with the current size and status established in 1977 characterised by the eviction of local communities who had settled in the reserve since the Early Iron Age (McShane, 1990). It is further reported that Vwaza attracted several settlers owing to the species richness of large-sized mammals including elephants. As such, Vwaza became a route of trade, especially in ivory connecting yet another elephant-rich area of eastern Zambia to Lake Malawi through to the Indian coast (McShane, 1990).

Elements of co-management in the VMWR began in the early 1990s following the Wildlands and Human Needs Project championed by the World Wildlife Fund (WWF) (McShane, 1990). However, as was the case with many countries in the region, the lack of relevant supporting policy slowed down progress (Zulu, 2013). The management approach was revisited in 1996 following Malawi's attainment of multiparty democracy in 1994 and the adoption of a new constitution that emphasises the devolution of power to the people. The decentralisation process that started thereafter (Malawi Government, 1998) provided more thrust for local community involvement in decision-making processes including decisions regarding the management of natural resources.

Subsequently, in 2000, the DNPW entered into a governance and management agreement with the local communities living within a 5 km distance from the gazetted boundary of the VMWR. Among the items included in the agreement are: (i) the Resource Use Programme (RUP), whereby members of the communities bordering the VMWR are issued with permits allowing them to harvest prescribed resources from the reserve within the 5km distance from the reserve border into the park; (ii) a revenue sharing scheme, whereby communities receive a fraction (currently at 25%) of the total revenue accrued from park entry and concession fees for community development projects. In return, communities are expected to perform several voluntary activities meant to foster the conservation of biodiversity such as surveillance, ensuring the protection of the wire fence, and reporting any suspected prohibited activities. For governance purposes, Natural Resources Committees (NRCs) were established at the village level. These are grouped into zones that operate at the Traditional Authority level. The Nyika-Vwaza Association (NVA) was subsequently established in 2003 as an umbrella body to coordinate the affairs of the communities in their respective zones and NRCs. The NVA encompasses two major and closely located PAs in northern Malawi, Nyika National Park and VMWR. By the time of this study, there were 60 NRCs in 12 zones against an initial 13 NRCs at the start of the programme in 2000.

According to the Extension Officer at the VMWR, Veronica Mhango (per. comm., April 2022), it was the communities themselves that demanded the formation of new NRCs over the years after realising the importance of being involved in the management and conservation of natural resources under the co-management approach.

Sampling and data collection

We used a multi-stage sampling approach where we selected five of the 12 zones and 20 of the 60 NRCs. A somewhat similar approach was used in the area by van Velden et al. (2020). The major differences from van Velden et al. (2020) are that we selected heads of households within the 5km distance from the reserve boundary that had lived in the area from the inception of co-management (not less than 25 years) since the purpose of our study was to assess the impact of the change in the conservation approach; while van Velden et al. (2020) used individuals above 18 years old from 231 households. Secondly, we only selected zones with proportionally reported greater activities in the reserve (McShane, 1990; O'Sullivan, 2019). The zones considered were Bowe, Kazuni, Lake Kazuni, Lusani, and Thunduwike. Finally, from the pool of purposively selected key informants that met our criteria, we randomly selected both men and women, and members and non-members of the NRCs drawn from different villages.

We used face-to-face individual interviews to collect data. A semi-structured questionnaire (composed of closed-and open-ended questions) was used for the interview survey (Young et al., 2018; Rampheri et al., 2022). According to Young et al. (2018), semi-structured questionnaires are preferable as they take care of the shortcomings associated with structured (or close-ended) and unstructured (or open-ended) interviews. Indeed, closed-ended questions allow for the comparison of responses between respondents and for conducting quantitative analyses; while open-ended questions provide respondents an opportunity to freely express themselves and provide detailed responses (Rampheri et al., 2022). Data were collected between January and April 2022. But preliminary data that gave the impetus to this study was collected in 2010 under the auspices of the Rufford Small Grants for Nature Conservation.

We collected data on the socio-demographic attributes of respondents. These included gender, ethnic tribe, age, residence period, level of formal education, estimated distance from the reserve boundary, and membership status to NRC (member or non-member). To determine the prescribed resources that local communities obtain from the VNMR, respondents were asked to state the resources they directly obtain from the reserve under the RUP in the co-management arrangement. To examine the perceptions of local communities towards conservation, we first assessed (i) the perceived importance and/or benefit of the co-management approach compared to the previous approach; (ii) the willingness of non-members to join NRCs including their motivating reasons as an indicator of local community willingness to participate in conservation work; and (iii) perceived importance of conserving biodiversity in the VMWR about ecosystem services. We also investigated knowledge of their roles in the co-management arrangement. Finally, based on their experiences and/or lessons learnt from the co-management arrangement to date, respondents were asked to suggest actions for improvement on their part as communities and on the part of the DNPW.

We used secondary ecological data from annual reports at the DNPW as a proxy to examine the effectiveness of ecological conservation outcomes. Ecological data was on trends in animal populations (1985 – 2021 for 17 species), animal mortality (1988 – 2021 for 30 species), and prohibited activities (1993-2021). The DNPW collects animal population data through annual surveys using aerial transect counts followed by ground truthing using ground transects. This is mostly done during the dry season when visibility is good. Data collected includes animal species abundance which provides trends and population estimates. Animal mortality data is collected daily and reported every month during routine patrols by the park staff. Some of the parameters collected include species name, status of carcasses (including, cause of mortality if possible), and GPS coordinates. Staff have cyber tracker gadgets which enable them collect GPS coordinates, track their routes and estimate coverage for monthly patrols. The collected data is aggregated annually. As for the prohibited activities, the DNPW in VMWR, like in other PAs in Malawi uses several parameters to assess and categorise these activities. These include dead animals, gunshots from poachers, snares encountered in the reserve, tree cutting, and signs of illegal camps encountered in the reserve. Data on prohibited activities is collected during routine daily and monthly patrols, when dealing with problem animal control, and when conducting annual ground animal surveys.

Approval to conduct this research was sought at different stages. The study was conducted in conformity with the requirements of Mzuzu University Research and Ethics Committee (MZUNIREC). Approval was also granted by the Director of the DNPW. Thereafter, verbal approval was sought from the leadership of the Nyika Vwaza Association, and the Resource Use Committees and local village heads in Vwaza. Moreover, participation by local communities was also based on their willingness to participate following a verbal free, prior informed consent.

Data analysis

Descriptive statistics were used for data analyses to describe trends. Specifically, bar charts were used to illustrate the prescribed resources (%) obtained from the studied communities in the VMWR and the perceived importance of conserving biodiversity in the VMWR. Pie charts were used to show local community perceptions of the importance of co-management in the VMWR, Further, various diversity indices including the Simpson (*1-D*), Shannon (*H*) and Evenness (e^H/S) were computed to depict the diversity and patterns of use of wild resources/NTFPs among the five zones. For this purpose, we treated a particular wild resource/NTFP (e.g., fruits, medicine, mushroom) as a "species" such that the citation of a resource was considered its presence while non-citation was its absence. Diversity indices have been used to show patterns of

use and knowledge of non-timber forest products in several studies, with evenness indicating the distribution of the resource (e.g., Ladio and Lozada, 2004). For instance, higher evenness (values closer to 1) indicates similar distribution of the resource in the area.

The population of animal species as estimated by the VMWR was recorded as individuals per species per year of estimation and a line graph was plotted to show the abundance trend for each species (Western et al., 2009). The same was done for animal mortality. For prohibited activities, the number of dead animals encountered per year and the number of activities and/or events encountered were also plotted in line graphs to show variations in trends. We built a Sankey diagram of the suggestions made by communities using the SankeyMATIC software (https://sankeymatic.com/build/) to show their relative importance. Sankey diagrams are one of the visual tools. They are used for illustrating categories of information and how their flow relates to each other with proportional arrow magnitudes (https://www.sankey-diagrams.com/). They have wide applications in different disciplines including natural resource management (e.g., Brodie et al., 2022). A correlation analysis was also done to assess which of the suggestions were correlated. The rationale for this was to identify convergent and non-convergent suggestions which may reflect synergies and trade-offs. All descriptive statistics were calculated in R software (R Development Core Team, 2021).

Finally, we tested whether (and how) the socio-demographic attributes of the respondents (gender, age, level of formal education, distance from the reserve boundary, and membership status (member vs non-member of NRC) influence community choices, knowledge, and perceptions about conservation work in the VMWR. The data consisted of two dependent binary variables for reasons for participation in the community management (benefits/incentives, and relationships), and three dependent binary variables regarding knowledge of the roles of NRC Community members (removing litter, community sensitisation, and removing snares or traps). Five socio-demographic independent variables, including gender (binary: male versus female), age (categorical with three levels: young, adult, and old persons), level of formal education (categorical with four levels: none, primary, secondary, tertiary), distance from the reserve boundary (categorical with two levels: short, and long), and membership status (two levels: member vs non-member of NRC) were considered to assess their effects on the dependent variables. One commonly used approach is to apply a binary logistic/probit model on each binary dependent variable and considering the five independent variables. However, this approach is not efficient mainly because we have multiple dependent variables which may be correlated. For instance, the response of an informant concerning benefits or incentives could be linked to his/her response concerning relationships. The multivariate probit (MVP) model is a generalisation of the probit model used to estimate several correlated binary outcomes jointly (Campbell et al., 2013; Mittal and Mehar, 2016). The MVP accounts for correlated responses when estimating the effect of predictors on dependent variables and is more efficient than applying several univariate logistic/probit models. The model was implemented in STATA (version 15.1, STATA Corporation, College Station, TX, USA) with the function *mvprobit* program. This function uses a simulated maximum likelihood estimation approach to provide robust parameter estimation (Cappellari and Jenkins, 2003).

Results

Socio-demographic characteristics of the respondents

A total of 160 individuals (46.25% women: 53.75% men), mostly belonging to the Tumbuka ethnic tribe (77.50%), with a few Ngoni (11.88%) and two other tribes (Lambya and Chewa) participated in this study. The majority of the respondents (58.13%) were under 40 years old and most had lived in the area for nearly 30 years (56.26%), with farming as their main occupation (96.25%). Slightly over half of the respondents (55.00%) had attained formal education to the primary school level, and most of them (76.25%) were residing within a 3km distance from the reserve boundary. While 50% of the respondents belonged to various NRCs, only 42.5% of these had been members for up to five years (Table 1).

Resources legally obtained from the VMWR by local communities

The respondents cited 11 prescribed wild resources (non-timber forest products) that they obtained from the VMWR under the RUP. Among the most cited resources were medicine (93%), mushrooms (91%), and edible fruits (69%), while reeds (11%) and sisal (1%) were among the least cited (Figure 2).

Among the five zones, three diversity indices [Simpson (1-D), Shannon (H'), and Evenness (e^H'/S) consistently flagged Thunduwike Zone (S = 9; N = 234) as a zone where local communities obtained comparably high diversity of wild resources (non-timber forest products including fruits, medicine, mushrooms) followed by Lake Kazuni Zone (S = 10; N = 173) (Table 2).

Perceptions of local communities of conservation

Local communities' perceptions of the importance of co-management in the VMWR

Compared to the era before co-management was introduced, nearly all the respondents (99%; n = 160) expressed positive perceptions towards co-management stating that things had somehow improved following its introduction in the VMWR, with only 1% indicating the opposite. Principally, respondents indicated that co-management had: (1) improved the relationship between communities and the park staff (99% of the respondents); (2) provided local communities with legal access to prescribed resources to complement their daily needs (98% of the respondents); and (3) brought tangible benefits to the area

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TABLE 1 Socio-demographic characteristics of the respondents in the VMWR by Zone.

Parameter	Zone					
	Bowe	Kazuni	Lake Kazuni	Lusani	Thunduwike	Total
Gender						
Female	14(43.75)	13(40.63)	18(50.26)	9(28.13)	20(62.50)	74(46.25)
Male	18(56.25)	19(59.38)	14(43.75)	23(71.88)	12(37.50)	86(53.75)
Tribe						
Tumbuka	25(78.13)	24(75.00)	26(81.25)	25(78.13)	24(75.00)	124(77.50)
Ngoni	1(3.13)	7(21.88)	4(1250).	3(9.38)	4(12.50)	19(11.88)
Others	6(18.75)	1(3.13)	2(6.25)	4(12.50)	4(12.50)	17(10.63)
Age						
Young: age≤ 40 years	19(59.38)	16(50.00)	15(46.88)	23(71.88)	20(762.50)	93(58.13)
Adult: 40 <age ≤ 60 years	12(37.50)	14(43.75)	15(46.88)	8(25.00)	8(25.00)	57(35.63)
Old: age> 60 years	1(3.13)	2(6.25)	2(6.25)	1(3.13)	4(12.50)	10(6.25)
Residential period						
≤30 years	16(50.00)	12(37.50)	23(71.88)	16(50.00)	23(71.88)	90(56.25)
>30 years	16(50.00)	20(62.50)	9(28.13)	16(50.00)	9(28.13)	70(43.75)
Main occupation						
Farmers	28(87.50)	30(93.75)	32(100.00)	32(100.00)	32(100.00)	154(96.25)
Others	4(12.50)	2(6.25)	0(0.00)	0(0.00)	0(0.00)	6(3.75)
Level of formal education						
None	1(3.13)	1(3.13)	3(9.38)	0(0.00)	2(6.25)	7(4.38)
Primary	17(53.13)	23(78.88)	19(59.38)	13(40.63)	16(50.00)	88(55.00)
Secondary	12(37.50)	8(25.00)	10(31.25)	19(59.38)	13(40.63)	62(38.75)
Tertiary	2(6.25)	0(0.00)	0(0.00)	0(0.00)	1(3.13)	3(1.88)
Distance from reserve boundary						
0 - 3 Km	18(56.25)	20(62.50)	2990.63)	31(96.88)	24(75.00)	122(76.25)
3.1 - 5 Km	14(43.75)	12(37.50)	3(9.38)	1(3.13)	8(25.00)	38(23.75)
Membership period to NRCs						
Non-member	16(50.00)	16(50.00)	16(50.00)	16(50.00)	16(50.00)	80(50.00)
Member						
1-5 years	14(43.75)	13(40.63)	13(40.63)	13(40.63)	15(46.88)	68(42.50)
6-10 years	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
11-15 years	1(3.13)	0(0.00)	3(9.38)	2(6.25)	1(3.13)	7(4.38)
16-20 years	0(0.00)	1(3.13)	0(0.00)	1(3.13)	0(0.00)	2(1.25)
>20 years	1(3.13)	2(6.25)	0(0.00)	0(0.00)	0(0.00)	3(1.88)

Values in parentheses are percentages.

including community development projects and household livelihood interventions. Some of the community development projects initiated in various areas included school blocks, bridges, and boreholes. At the household level, interventions cited included small livestock pass-on programmes and carbon payment schemes.

Willingness and motivating factors for community participation in conservation work

About 83.75% (67 out of 80) of the non-members of the NRCs that participated in the study expressed willingness to join and participate in conservation work in the area. The respondents cited

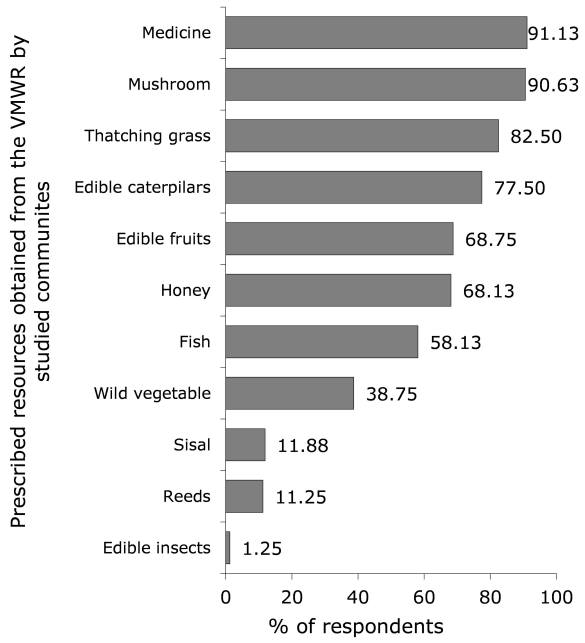

FIGURE 2
Prescribed resources obtained from the VMWR by the studied communities.

three motivating factors, namely (1) benefits and/or incentives that members of the NRCs get (100%); (2) the urge to take part in management decision-making for the Reserve (98.51%); and (3) the feeling to further help build the relationship between communities and the park staff (16.42%). Some of the benefits and/or incentives mentioned included temporary employment or piece works in the reserve, tours to various PAs, livestock pass-on programmes, and first-hand access to information regarding community development programmes in the area.

Perceived importance of conserving biodiversity in the VMWR

Other than direct utilitarian benefits obtained from the VMWR, respondents were asked to mention the importance of conserving biodiversity in the reserve. In this regard, the respondents demonstrated having adequate knowledge of the various ecosystem services that biodiversity in the VMWR brings to the area. These included climate regulation (100% of the respondents), carbon sequestration (99.38% of the respondents), and pollination (99.38%) (n=160) (Figure 3).

Key roles of local communities in the co-management arrangement in the VMWR

Both members and non-members of the NRCs demonstrated knowledge of local communities' roles in the conservation of biodiversity in VMWR under the co-management arrangement. Some of the key roles cited included patrolling and reporting illegal activities (87% of the respondents) and removing litter, especially plastics from along the wire fence (51% of the respondents) (n=160) (Figure 4).

Trends in animal populations, animal mortality, and prohibited activities in the VMWR

Animal population trends

The results showed that animal species populations were relatively much higher by 1985 but they almost crashed by 1996 (Figure 5). The only remarkable exception in this regard was the elephant (*Loxodonta africana*) population. For instance, the population of buffaloes (*Syncerus caffer*) decreased from a record 900 (1985) to only less than 200 in 1996 and since then an average of 151.33 (median = 147) buffaloes have been recorded per year. On the other hand, no individual eland (*Taurotragus oryx*) had been spotted in the reserve after 1996 from an estimated population of 75 animals in 1985; while zebra (*Equus quagga*) appears to have only re-emerged in 2007 since 1985, and average of 7.86 individuals had since been recorded in the surveys between 2007 and 2021 (Figure 5A). The population of roan antelope (*Hippotragus equinus*) decreased from 700 (1985) to barely less than 100 animals by 1996 (Figure 5B). Since then, its population has remained roughly below 200 (mean = 159; median = 162). Similarly, there were approximately 1000 common duikers (*Sylvicapra grimmia*) and 700 bushbucks (*Tragelaphus scriptus*) in 1985 but the population sizes of these two species had reduced drastically to <100 and 10 by 1996 for the common duiker and bushbuck, respectively (Figure 5C) and have continued to fluctuate below 100 animals to date. A similar trend was observed for warthog (*Phacochoerus africanus*) and grysbok (*Raphicerus meanotis*). There were about 1500 warthogs and 1000 grysbok in the mid-1980s, but the populations of these two species drastically

TABLE 2 Diversity of NTFPs in the studied five zones in the VMWR based on three diversity measures [Simpson (*1-D*), Shannon (*H'*), and Evenness (e^*H'*/*S*).

Metric	Bowe	Kazuni	Lake Kazuni	Lusani	Thunduwike
Taxa (*S*)	8	10	9	10	9
Individuals (*N*)	175	153	228	173	234
Simpson (*1-D*)	0.853	0.867	0.877	0.852	0.885
Shannon (*H'*)	1.944	2.101	2.103	2.001	2.172
Evenness (*e^H'/S*)	0.874	0.817	0.910	0.740	0.976

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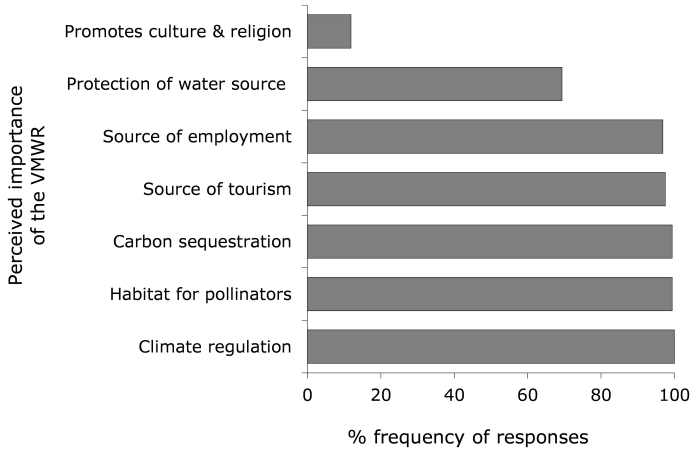

FIGURE 3
Perceived importance of conserving biodiversity in the VMWR.

reduced to <100 animals by 1996 and have remained almost the same to date (Figure 5D).

Animal mortality

Generally, the results showed an increasing trend in animal mortality over the period (Supplementary Figure 1). This was particularly evident for large body-sized mammals such as elephant, buffalo, and hippopotamus (Supplementary Figure 1A), large-antelopes e.g., roan antelope and kudu, and medium-sized antelopes e.g., bushbuck and impala (Supplementary Figures 1B, C), and for warthog (Supplementary Figure 1D). As expected, the trend was less conspicuous for the non-edible species in the area such as the mongoose (Supplementary Figure 1E) and carnivorous animals like leopards (Supplementary Figure 1F).

Prohibited activities

The results showed an increasing trend in the number of animals found dead in the reserve attributable largely due to poaching, with an annual average of 2.27 (median = 1.5) elephants and 21.82 (median=18.5) other species over the period of 1993-2021 (Supplementary Figure 2A). Further, the number of snares found in the reserve (annual mean=378.64; median=151.5) and cut trees (annual mean=234.73; median=222.5) also showed an increasing trend over the same period (Supplementary Figure 2B).

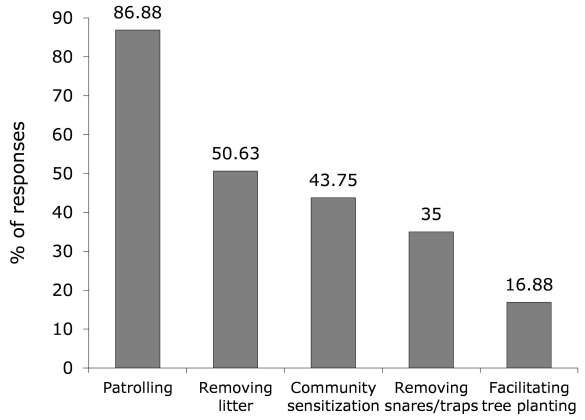

FIGURE 4
Key roles of local communities in the co-management arrangement in the VMWR.

Suggestions for improvement in the co-management approach

As resource users, local communities suggested areas or actions they thought would enhance conservation and sustainable use of biodiversity in the VMWR under the co-management approach based on the lessons learnt over the years. On their part, most respondents suggested tree planting on communal land (75%) and livestock farming (72.50%). On the part of the DNPW, the communities suggested undertakings such as the provision of social amenities (65.63%), provision of small livestock such as goats (62.50%), and timely sharing of revenue accrued from the reserve (26.88%) (Figure 6).

When these suggestions were correlated, the results showed a somewhat moderate negative correlation between livestock farming and stopping poaching ($r \geq -0.45$), and a moderate positive correlation between tree cutting and stopping poaching ($r \geq 0.37$) (Table 3).

Socio-demographic factors influencing choices, knowledge, and perceptions of local communities on biodiversity conservation in the VMWR

The Multivariate probit (MVP) model showed that choices that local communities make about participation in conservation work significantly vary depending on their socio-demographic attributes ($P = 0.05$, $n = 160$) (Supplementary Table 1). The model showed

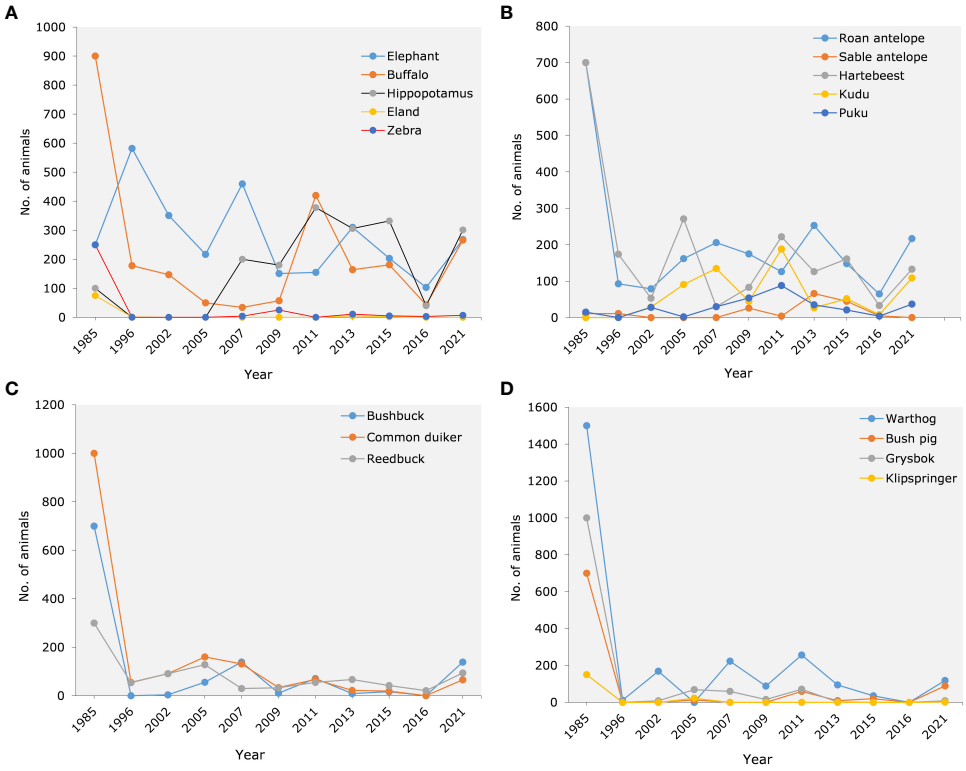

FIGURE 5
(A–D) Estimated population trends for 17 animal species in the VMWR from 1985-2021.

that age of individuals was the most influencing factor, with the probability of the old (age>60 years) citing benefits and/or incentives being significantly lower than that of the adults (40 <age ≤ 60 years) citing this reason as a motivating factor (*P = 0.004; S.E. = 0.471; coef. = -1.364)*. Gender, level of formal education, distance from the reserve boundary, and membership status did not affect this reason. However, female respondents frequently cited the need to help build the relationship between park staff and the local community more than did male respondents (*P = 0.005; S.E. = 0.325; coef. = -0.907*). The level of formal education, distance from the reserve boundary, and membership status did not affect this aspect. Further, there was a significant negative correlation between the two reasons (benefits and/or incentives and relationship with the park staff) (*rho21; P = 0.002; S.E. = 0.162; coef. = -0.496*) (Supplementary Table 1A).

Significant variations were observed among local communities regarding knowledge of their roles in the co-management arrangement (*P = 0.0001; n = 160*) largely influenced by gender and membership status of the respondents. It was found that the probability of male respondents citing removing litter was lower than female respondents (*P = 0.040; S.E. = 0.215; coef. = 0.441*). Whereas, the probability of non-members of NRCs citing removing litter was higher than members (*P = 0.002; S.E. = 0.218; coef. = 0.669*). However, non-members cited community sensitisation less frequently than members of the NRCs (*P = 0.011; S.E. = 0.217; coef. = 0.551*). Further, male respondents cited removing snares more frequently than female respondents (*P = 0.003; S.E. = 0,226; coef. = 0.668*), while non-members cited this role less frequently than did members of the NRCs (*P = 0.002; S.E. = 0.227; coef. = 0.716*). The model further showed that there were significant negative correlations between removing litter and community sensitisation (*rho21; P = 0.003; S.E. = 0.116; coef. = -0.351*), removing litter and removing snares (*rho31; P = 0.026; S.E. = 0.122; coef. = -0.272*), and community sensitisation and removing snares (*rho32; P = 0.008; S.E. = 0.127; coef. = -0.336*) (Supplementary Table 1B).

Discussion

This study assessed the extent to which co-management has effectively contributed to biodiversity conservation and socio-economic development outcomes in the Vwaza Marsh Wildlife Reserve based on perceptions of local communities bordering the reserve. It also utilised secondary ecological data on trends in the animal population, animal mortality, and prohibited activities. The results are discussed in the subsequent thematic subsections, and implications for conservation are suggested under each theme.

Local communities' access to resources in the VMWR

Based on the responses of the studied communities, it is evident that co-management has improved access by local communities to NTFPs in the VMWR thereby enabling them to meet their daily needs (*assumption one*). This is contrary to the previous management

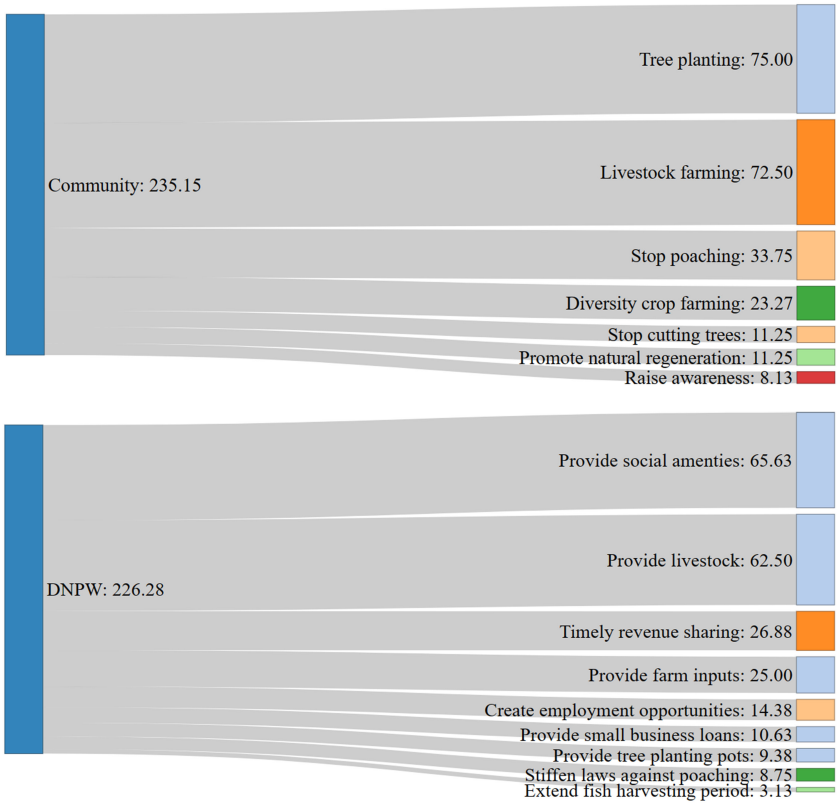

FIGURE 6
Sankey diagram showing suggested areas for improvement in co-management based on the perceptions of local communities in the VMWR; Responsible actors (left) and suggested actions (right). Numbers represent frequency of citation.

approach where the park-border communities were denied access to valuable resources in the reserve. Increasing benefits to local communities through RUPs is one of the preconditions for co-management and has been widely reported (e.g., Muhumuza and Balkwill, 2013), although some studies have reported otherwise. For instance, despite the introduction of co-management in Blouberg Nature Reserve in South Africa, the majority of the households interviewed (87%) ($n = 290$) reported not to have received benefits from the reserve (Rampheri et al., 2022). The reported discrepancies in the literature on benefits from PAs, according to Zhang et al. (2022), may in part point to differences in the cognition of benefits by communities with varying daily needs, influenced by different socio-economic, political, and cultural factors. This highlights the need for carefully assessing basic resources that are valuable to the park-border communities, since such resources may be crucial for co-management programme support (Shackleton and Shackleton, 2004).

Like in many developing countries, increasing cultural beliefs in medicines from natural products and limited access to conventional medicine (Drury, 2020), and perpetual food insecurity challenges make NTFPs an important source of health care service and a food security safety valve in southern Africa (Shackleton and de Vos, 2022). It is not surprising, therefore, to find medicine and food (including mushrooms, edible caterpillars, and edible fruits) being some of the important resources cited by local communities in the VMWR. Medicine and food are two of the important resources upon which livelihoods of many rural people rely worldwide (Shackleton and de Vos, 2022).

Further, the results showed slight spatial variations in the diversity of resources accessed by the park-border community, with communities in the Thunduwike Zone using a somewhat relatively higher diversity of resources (Table 2). This may reflect differences in resource use among zones with a more intense use and dependence on the VMWR in the eastern side of the reserve where the Thunduwike zone is located or it may perhaps indicate a relatively higher diversity of resources found in this area. Increased human pressure on biodiversity on this side of the reserve has been reported in previous reports (O'Sullivan, 2019). These results may be used to guide where more focus on intense monitoring of the RUP should be done in collaboration with the NRC members.

Although access to basic resources by the bordering communities is not in itself a panacea for effective conservation and has also been blamed for conflicting ecological principles of conservation (Shova and Hubacek, 2011; Muhumuza and Balkwill, 2013), many other studies have suggested that local communities are likely to value and support conservation work if such initiatives address their basic needs (Shackleton and Shackleton, 2004; Gordon, 2017; Woodhouse et al., 2022). This is especially true in developing countries like Malawi, given the heavy dependency on forest and wildlife resources of the park-border communities in these countries to meet their livelihood needs (Muhumuza and Balkwill, 2013; Shackleton and de Vos, 2022).

TABLE 3 Correlation matrix of the suggested areas for improvement in co-management in the VMWR.

	Stop poaching	Stop cutting trees	Livestock farming	Tree planting	Raise awareness	Diversify crop farming	Promote natural regeneration	Provide social amenities	Provide livestock	Timely revenue sharing	Provide farm inputs	Create employment opportunities	Provide business loans	Provide tree-planting pots	Stiffen laws against poaching	Extend the fish harvesting period
Stop poaching	1.00															
Stop cutting trees	0.37	1.00														
Livestock farming	-0.45	-0.36	1.00													
Tree planting	-0.38	-0.16	0.03	1.00												
Raise awareness	0.08	-0.11	-0.18	-0.30	1.00											
Diversify crop farming	-0.02	-0.11	0.06	-0.25	-0.05	1.00										
Promote natural regeneration	-0.21	-0.13	0.04	0.02	-0.03	0.05	1.00									
Provide social amenities	0.02	-0.20	0.06	0.16	-0.12	0.04	0.01	1.00								
Provide livestock	-0.10	-0.09	0.07	-0.03	0.09	0.05	-0.01	-0.21	1.00							
Timely revenue sharing	0.04	0.23	-0.07	0.02	-0.03	-0.06	0.05	-0.15	-0.05	1.00						
Provide farm inputs	-0.05	-0.02	0.00	-0.10	0.04	0.05	-0.02	-0.19	0.36	0.01	1.00					
Create employment opportunities	0.27	0.14	-0.19	-0.13	0.20	-0.06	-0.15	-0.19	-0.23	-0.01	-0.07	1.00				
Provide business loans	-0.03	0.01	0.08	0.06	-0.03	-0.02	-0.06	-0.31	-0.03	0.11	0.04	-0.08	1.00			
Provide tree-planting pots	0.00	0.09	0.05	-0.01	-0.10	-0.01	-0.11	-0.08	0.16	-0.19	-0.04	-0.13	-0.11	1.00		

(Continued)

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TABLE 3 Continued

	Stop poaching	Stop cutting trees	Livestock farming	Tree planting	Raise awareness	Diversify crop farming	Promote natural regeneration	Provide social amenities	Provide livestock	Timely revenue sharing	Provide farm inputs	Create employment opportunities	Provide business loans	Provide tree-planting pots	Stiffen laws against poaching	Extend the fish harvesting period
Stiffen laws against poaching	-0.08	-0.04	0.04	-0.03	-0.01	-0.06	0.10	-0.10	-0.13	-0.04	-0.08	-0.13	-0.11	-0.10	1.00	
Extend the fish harvesting period	0.10	0.05	0.03	0.10	-0.05	-0.02	-0.06	0.05	-0.23	0.13	-0.10	0.03	0.05	-0.06	-0.06	1.00

Red, negative correlation; Blue, positive correlation.

Perceptions of local communities on conservation

Unlike other studies (e.g., Rampheri and Dube, 2021; Rampheri et al., 2022) that largely found negative community perceptions of nature conservation in PAs thus pointing towards failure of the co-management approach, the findings of the current study have shown that co-management had created a positive attitude towards conservation among the local communities bordering the VMWR (*assumption two*). Owing to this, and as noted in this study, even respondents that were not members of the NRCs were willing to become members of the NRCs so as to fully participate in the conservation work. The positive perceptions expressed by communities in the VMWR may relate to their increased access to valuable resources, involvement in biodiversity conservation, and social development programmes initiated in the area through the co-management arrangement. Similar results were found in Pendjari National Park in Benin (Vodouhê et al., 2010). According to Vodouhê et al. (2010), the positive behaviour of local communities towards conservation of biodiversity within the Pendjari National Park was highly correlated with the effective involvement of local communities in the management strategy that involved more effectively local communities. Further, participants' perceptions of biodiversity conservation were strongly related to locally perceived benefits (Vodouhê et al., 2010).

Recently, a global summary of local residents' attitudes towards PAs (Allendorf, 2020) has shown that communities are more likely to be more positive towards less strict PAs than strict ones. Bennett et al. (2019) found that perceptions of good governance and social impacts were stronger predictors of increasing support for conservation work among small-scale fishermen in marine PAs from six countries in the Mediterranean Sea. Besides, it is widely considered that people's positive perceptions of protected areas are not only a key indicator of PA conservation success (Allendorf, 2020) but they also ultimately ensure the support of local constituents thus enabling the long-term success of conservation work (Bennett, 2016). Therefore, the positive perceptions of conservation work as found in the VMWR point to a somewhat successful co-management in the area. Importantly, the perceptions provide an opportunity to achieve greater and more effective long-term support for conservation initiatives in the VMWR.

The finding that local communities were able to associate the biodiversity of the VMWR with various benefits they get from the reserve including regulating benefits (e.g., pollination), material benefits (e.g., water source), and non-material benefits (e.g., tourism) (Figure 3) is a demonstration of their appreciation of nature's contribution to people. This appreciation, according to (Allendorf and Yang, 2013), is important for local communities to recognise a common ground between their livelihoods and a PA. These results are consistent with the recent findings in the PAs of the *Sundarbans* mangroves of Bangladesh, where co-management has built an awareness in favour of biodiversity conservation and the efficient use of natural resources (Rahman, 2022). Such an awareness of the people's already-existing perceptions, according to Allendorf and Yang (2013) and McShane et al. (2011), may provide a conducive environment to initiate a discussion of win-win

scenarios regarding conservation work. These findings further provide hope for a successful conservation arrangement in the VMWR, given the shreds of evidence that conservation efforts are likely to succeed if local communities become aware of the values of conservation in form of various ecosystem services accrued to them (Allendorf and Yang, 2013; Muhumuza and Balkwill, 2013).

Co-management and extraction of prohibited resources

The animal population crash and the increase in animal mortality in the VMWR around the mid-1990s seem to have coincided with the political wind of change that took place in Malawi and the political environment that ensued after 1994 in the nascent years of multiparty democracy. Two factors could explain these observations. With the wind of democratic rights and freedoms, either some pockets within the local communities thought this was their time to claim what was forcefully taken away from them following their eviction from the park, or the DNPW suddenly became overwhelmed as the previous management approach of coercion could no longer be used. The upsurge in lawlessness in the reserve during this transition might have led to either killing of animals or migration of animals to other areas such as Nyika National Park and neighbouring Zambia. Although it has been suggested that there is generally no uniform relationship between democracy and the state of the environment (Arvin and Lew, 2011), evidence abound in the literature of increased prohibited activities and biodiversity loss linked to democracy, especially in countries with low economies and young democracies (Buitenzorgy and Mol, 2011; Rydén et al., 2020). For instance, Buitenzorgy and Mol (2011) suggest that countries in democratic transition experience the highest deforestation rates compared to non-democracies and mature democracies. Besides, indicators of increasing levels of prohibited activities such as poaching and growing requests for land and accessibility to the VMWR were reported prior to 1994 (McShane, 1990). Although this study did not ask the respondents about illegal activities undertaken in the area and associated threats to biodiversity in the reserve, the mentioning of removal of snares (35%) as one of the key roles of the communities (Figure 4) and the suggestion to stop poaching by nearly 34% of the respondents (Figure 6) as one of the ways to improve co-management in the area signify indirect admission of the seriousness of poaching in the reserve by the communities themselves. While several factors such as climate change and loss of suitable habitat may negatively impact animal populations, poaching is regarded the major factor associated with declining wildlife populations in Africa (Mutti et al., 2023). It may be suggested, therefore, that poaching was more serious prior to the establishment of co-management, especially in the transition period into multiparty democracy, which might have led to the animal population crashes in the VMWR (Figure 5).

According to Allendorf et al. (2012), higher levels of community participation are generally related to higher levels of compliance. However, our study found increasing trends in prohibited activities even after the introduction of co-management. At this stage, those that are actually involved in prohibited activities are not known: is it members of the NRCs or non-members or both, or other people outside the border zone? Nonetheless, the finding contradicts our expectation that co-management would reduce or completely avoid the occurrence of prohibited activities in the reserve (*assumption three*). Interestingly and encouragingly, despite the increasing trend in the reported prohibited activities, most species seemed to have recovered from the crash they suffered in 1996 after 2000 including the record re-emergence of the zebra, coinciding with the establishment of co-management (Figure 5). It maybe suggested therefore that the observed trends in prohibited activities probably reflect a continuation of an existing trend that was otherwise less reported prior to the introduction of co-management. It may also imply that probably increased efforts of removing traps and snares are paying dividends.

Our study did not assess reasons behind the increasing trends in prohibited activities in the VMWR. However, van Velden et al. (2020) have suggested that hunting for income, a preference for the taste of wild meat and added diversity in the diet are key drivers of bushmeat consumption in Malawi. In their exploratory study on the prevalence of hunting and consumption of wild meat in four PAs in Malawi including the VMWR, van Velden et al. (2020) found that nearly 39% and 4 -19% of the population (n=1562) consumed wild meat and engaged in hunting, respectively, with consumption being more prevalent in poorer households. This may mean that poaching, probably driven by poverty and culture, is still an issue in the VMWR despite the introduction of co-management. Indeed, poverty (Knapp, 2012; Matseketsa et al., 2022) and a culture of hunting for bushmeat (Tuu et al., 2008; Viollaz et al., 2022) have been reported as key drivers of non-compliance in PAs. According to Muhumuza and Balkwill (2013), such factors may make some members of communities unable to appreciate incentives obtained from PAs but get involved in prohibited activities like poaching. For example, it has long been suggested that poor people may be forced to overexploit wildlife resources even if they are faced with various sanctions including arrests, fines, and imprisonment (McShane, 1990; Knapp, 2012).

On the other hand, while some people may be aware of the prohibited activities but offenses such as poaching may not be viewed as deviant (Viollaz et al., 2022) since bushmeat has all along been consumed as part of their tradition and culture (Tuu et al., 2008). Similar cultural and traditional practices have been raised to justify claims for access to resources in other ecosystems including aquatic ecosystems (Williams, 2021). Thus, it may be suggested that some members of the local communities in the VMWR might have taken advantage of the RUP to undertake prohibited activities like snaring in the reserve. Involvement of resource use committees in prohibited activities and practices of corruption have been reported in Bangladesh (Rahman, 2022) and Kibale National Park in Uganda (Solomon et al., 2012). Moreover, local community accessibility to reserves has also been implicated in driving prohibited activities in other PAs such as the Bwindi Impenetrable National Park in Uganda (Bitariho et al., 2022) and Bardia National Park in Nepal (Shova and Hubacek, 2011).

The increasing trend in snaring in the VMWR is worrisome (Supplementary Figure 2B), as is globally the case (Watson et al.,

2013; Gray et al., 2018). According to Gray et al. (2018), snaring is one of the major drivers of defaunation since snares are cheaply made, easy to set, difficult to detect, and indiscriminate. As such, while removal of snares was reported in the VMWR, Gray et al. (2018) argue that removal alone is largely ineffective as snares will continuously be replaced in the absence of proactive search, arrest, and prosecution of snare-setters, along with incentives not to hunt. Several suggestions aimed at curbing prohibited activities such as snaring have been made elsewhere including compensating local communities to forfeit overexploitation of natural resources (Amadu et al., 2021), criminalising the possession of snares (Gray et al., 2018), and provision of alternative livelihood interventions (Gray et al., 2018; Brittain et al., 2022; Willis et al., 2022). For instance, park-border communities in northern Ghana have demonstrated willingness to accept an average annual amount of GH¢3346.26 (US$ 339.36) and GH¢1487.67 (US$ 150.87) per household as compensation to forfeit the exploitation of market and non-market forest resources, respectively (Amadu et al., 2021). Unfortunately, while compensation may help curb snaring and other prohibited activities, implementation of this strategy in many PAs including the VMWR may not be sustainable, considering that most PAs in Africa have a limited financial resource base for PA management (Muhumuza and Balkwill, 2013; Baghai et al., 2018).

On the other hand, Gray et al. (2018) have suggested legislative reform in Southeast Asia that criminalises the possession of snares including materials used for their construction, inside and in the border zone of PAs, as well as consistent enforcement of such legislation as a way of curbing poaching. This, according to Gray et al. (2018), ought to be combined with longer-term awareness-raising activities aimed at changing cultural attitudes and behaviours related to the consumption of wildlife products. However, considering that law enforcement based on arrests and fines alone may not be effective against poaching (Knapp, 2012; Moreto and Charlton, 2021), proactive snaring prevention through use of informal guardianship as advanced by Viollaz et al. (2022) could become a useful strategy in the VMWR. This also bodes well with the proposition of a community problem-solving policing model where local communities are actively involved in anti-poaching (Moreto and Charlton, 2021). Mapping of prohibited activities such as poaching could therefore serve as a starting point to guide park managers in the VMWR in the formulation of targeted management strategies in this regard (Degbelo et al., 2022). The work initiated in VMWR by McShane (1990) on the spatial mapping of prohibited activities may provide a valuable baseline in this respect.

Alternative livelihood interventions implemented at the household level and supported by awareness raising that address both food (animal protein) and income have also been suggested as possible strategies (Brittain et al., 2022; Willis et al., 2022). For instance, a recent study in Dja Faunal Reserve in Cameroon on alternative livelihood interventions (Brittain et al., 2022) has shown that alternative projects that offer both food and income-generating activities could reduce household rates of hunting and consumption of wild meat. Therefore, for successful alternative livelihood projects in the VMWR, an understanding of the characteristics of alternative projects preferred by the communities using a scenario-based approach (Brittain et al., 2022) may be considered before the finalisation and implementation of project designs.

Given that communities around the VMWR are primarily farmers, and that prohibited activities in the area tend to increase with declining human food security (van Velden et al., 2020), agricultural-related interventions suggested by the communities themselves (Figure 6) would probably improve the economic activities in the area. These may help reduce reliance on wildlife-based economies. This is also important considering that local community involvement in the current community development projects seems to be failing to reduce the hunting and consumption of wild meat (van Velden et al., 2020). However, given the growing human population size around the VMWR and associated soil degradation (McShane, 1990; van Velden et al., 2020), indigenous multipurpose tree species with the potential to increase agricultural production and selected in a participatory manner with farmers (Leakey et al., 2022) could play a critical role in this regard. Crucially, participatory revision of the access permit, especially the need for park staff to accompany communities during resource collection activities as recommended in Majete Wildlife Reserve (Gordon, 2017) ought to be considered in the VMWR.

Co-management as a problem-solving platform for improved human well-being

It has long been suggested that co-management is not a fixed state but a continuous problem-solving process evolving over time (Berkes, 2009). It would, therefore, seem that the initial phases of co-management have provided local communities in the VMWR with a platform to rethink their problems and learn from their past experiences with co-management. This has enabled them to suggest various ways of improving not only their quality of life (*assumption four*) but also biodiversity conservation (Figure 6). These suggestions may be crucial for developing an adaptive co-management in VMWR that could increase both conservation and development goals. Moreover, adapting natural resource management based on the feedback from resource users, according to Meijaard et al. (2021), could lead to positive outcomes for both the environment and the well-being of people. However, it is also recognised that benefits from co-management implementation may take a while, given that this is a new phenomenon (Pailler et al., 2015), thus underscoring the need for a continued search for ways to improve the co-management approach based on the socio-economic, cultural and political contexts. Therefore, the suggestions made by the local communities in VMWR may further be explored, and the scenario-based approach (Brittain et al., 2022) could become a useful tool in this respect. Such an exploration could help come up with feasible and targeted interventions relevant to the local communities in the VMWR (Allendorf et al., 2012).

Age, gender, and membership to a natural resource institution of local communities influence their decisions, knowledge, and perceptions in the VMWR

Our results have shown that age, gender, and membership to the NRC influence conservation decisions, knowledge, and perceptions of local communities in the VMWR, partly confirming our last assumption (*assumption five*). This is consistent with many other studies (Muhumuza and Balkwill, 2013) that show the influence of these three factors on conservation work. Specifically, our results show variations in factors driving decisions for participation in conservation work based on age. That adults (40 <age ≤ 60 years) cited benefits more than old individuals (age>60 years) as a motivating factor may mean that adults are perhaps driven by material benefits more than other benefits of biodiversity as a source of livelihood to fend for their families. This suggests that adults more than the old individuals in the VMWR are likely to engage in prohibited activities, given that older individuals are more likely to engage with nature and avoid environmental harm in their behaviours (Wiernik et al., 2013).

The results have further revealed the underlying gender disparities prevalent in the area of natural resources management. It would appear gender norms and practices have shaped the knowledge and perceptions of community members in the VMWR, with different roles ascribed to a different gender. For instance, women appear to get more involved in removing litter as opposed to men who cited removing snares more than women. Traditionally, hunting for bushmeat is done by men. As such, men are better placed to identify traps and snares. Similar observations regarding differences in community roles based on gender have been reported in forest-fringe communities in Ghana (Asumang-Yeboah et al., 2022). Further, like in many countries in Africa where belongingness to an organisation increases knowledge of communities about biodiversity conservation (Muhumuza and Balkwill, 2013), members of NRCs in the current study seemed to be more exposed to information about the roles of communities in the co-management. These results generally highlight the importance of paying attention to community differentiation and attributes such as age, gender, and membership to local institutions, as inattention to such factors may limit the potential effectiveness of co-management (Muhumuza and Balkwill, 2013; Viollaz et al., 2022).

Conclusions

We used a combination of perceptions of local communities and ecological data (trends in animal population, mortality, and prohibited activities) to assess the extent to which co-management has effectively contributed to biodiversity conservation and socio-economic development outcomes in the Vwaza Marsh Wildlife Reserve (VMWR). This study has shown that populations of most animal species are showing recovery signs from the crash suffered during the period prior to the establishment of co-management. It has also shown that co-management has created positive perceptions of local communities of conservation and socio-economic development work in the area, thus partly indicating the success of the management approach. The positive perceptions are attributable to improved benefits from the reserve and improved park-people relationships. Furthermore, the study has shown that co-management can provide an opportunity for an actively engaged community to make suggestions that aim at improving not only their quality of life but also ecological goals. Considering the resource constraints (financial and human) in the VMWR, as is common with PAs in the global south (Watson et al., 2014), and given that this is a new management approach in complex and context-specific relationships (Allendorf et al., 2012; Pailler et al., 2015), we conclude that while it might be too early to achieve both conservation and development goals, our findings provide hope for an adaptive and effective co-management in the VMWR. We recommend a study on the spatial distribution of traps and snares in relation to animal occupancy, resource use zone and core zone to help channel resources for monitoring. So too, a study to quantify sensitive behaviour related to prohibited activities including poaching using specialised questioning techniques such as the Randomized Response Techniques (RRTs) (Ibbett et al., 2023) would help establish the prevelaence of such rule-breaking behaviours among community members in the Vwaza. Further, future conservation activities in the area should take into consideration age, gender, and membership to natural resource committees (NRCs) of the local communities as these appeared to significantly influence local communities' decisions, knowledge, and perceptions of conservation work. Furthermore, misunderstandings over revenue sharing should be addressed transparently, as this might be a cause of conflict for the management of the VMWR. Finally, participatory evaluation of co-management in the VMWR, taking into consideration the findings of this study and lessons learnt over the years, is also recommended.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Mzuzu University Research and Ethics Committee. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. The study did not involve physical animals. It only used secondary ecological data of the animals (population and mortality).

Author contributions

Conceptualisation: LM; Data collection: LM and AK; Data analysis: KVS, SATA, and LM; Writing – draft manuscript: LM; Writing – review and editing manuscript: KVS, DN, WOM, AEA, and BS. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2023.1124142/full#supplementary-material

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