EFFECTS OF ENVIRONMENT AND GOVERNANCE ON FINANCIAL SUSTAINABILITY OF COMMUNAL CONSERVANCIES IN NAMIBIA

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ABSTRACT

Ecosystem services from tourism and governance of communal institutions are critical to financial sustainability of community-based natural resource management. I evaluated effects of large mammal occurrence and landscape attributes on incomes from hunting and photographic tourism earned by communal conservancies in Namibia during 1998–2022. I also evaluated effects of local management and governance on total income earned by Namibia's conservancies during 2011–2022. I compiled annual incomes and occurrence of 'Big 5' species (elephant [*Loxodonta africana*], buffalo [*Syncerus caffer*], black rhino [*Diceros bicornis*], lion [*Panthera leo*], and leopard [*P. pardus*]) using conservancy accounting and wildlife monitoring data. I compiled annual conservancy performance scores for natural resource management and institutional governance using 'event book' monitoring data. Hunting occurred in 70 of 86 conservancies and generated income almost twice as rapidly as photographic tourism. Hunting income increased with conservancy area and number of Big 5 species present but decreased with years since establishment and increasing mean elevation, topographic diversity, and distances to national parks. Photographic tourism occurred in 39 conservancies and generated 447% greater median annual income than hunting for conservancies earning >$0. Photographic income increased with years since establishment and higher annual precipitation but decreased with higher mean elevation. Large mammals are an important driver of income to Namibia's conservancies and hunting and photographic tourism can provide complementary benefits. Conservancies earning >$0 income generated a median annual of $60,518 since 2011. Income during 2011–2022 increased with years since establishment, higher management performance, presence of nongovernmental organization (NGO) support within conservancies, and annual general meeting (AGM) occurrence. Income during 2019–2022 also increased with higher governance performance. Median management and governance performances across conservancies were only about 50% of their maximum scores, indicating higher income potential with improved performance. Conservancies remained financially dependent on NGO support and AGMs were important functions for generating income. I recommend Namibia's conservancies, particularly those established more recently and with smaller area or without NGO presence, consider inter-conservancy wildlife co-management, collaborating with tourism industries, and prioritizing improved local management and governance to develop more sustainable community-based natural resource economies.

This thesis is dedicated to my Mother, the foundation of our family.

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INTRODUCTION

Integrating socioeconomic dynamics and indigenous peoples' rights in conservation are central to meeting global biodiversity protection goals (e.g., Global Biodiversity Framework; Sandbrook et al., 2023). Human dimensions of conservation are especially important in Africa where land use policies can cause conflicts among stakeholders (Musavengane & Leonard, 2022). Agropastoralists coexist with wildlife and depend on ecosystem services, creating complex relationships between natural resource management and development (Roe et al., 2013). As protected areas fail to support biodiversity (Craigie et al., 2010), effective governance of communal lands is needed for conservation (Garnett et al., 2018). Studying rural wildlife-based economies therefore includes aspects of biodiversity protection, sustainable development, and environmental justice (Snyman et al., 2021).

A new community-oriented conservation paradigm emerged in southern Africa following late 20th century postcolonial reform (Hulme & Murphree, 1999). The concept of community-based natural resource management (CBNRM) was influenced by common pool resource governance (Ostrom, 1990), rights-based decentralization of authority (Campese et al., 2009), and neoliberal commercialization of wildlife (Igoe & Brockington, 2007). Colonial policies during the 1960s–1970s allowed wildlife ranching on private lands (Barnes & Jager, 1996), which was more economically viable than livestock in dry marginal habitats (Child et al., 2012). Conditions on communal lands, however, necessitated further decentralization of user rights to produce conservation incentives (Child & Barnes, 2010).

Southern Africa's progressive policies in the 1980s–1990s developed into national CBNRM programs led by Zimbabwe's Communal Areas Management Program for Indigenous Resources Association (Taylor, 2009), community trusts in the Chobe Enclave and northern Botswana (Jones, 2002), Administrative Management Design for game management areas in Zambia (Marks, 2001), and communal conservancies in Namibia (Jacobsohn & Owen-Smith, 2003). These programs were designed to remove colonial-era discrimination in land use policy by a democratic devolution of rights to local communities, linking wildlife management with development opportunities, and providing conservation incentives through socioeconomic benefits (Murphree, 2009). Post-reform CBNRM programs increased wildlife abundance on communal lands and rapidly generated income (Suich et al., 2009).

In Namibia, establishment of conservancies in the late 1990s facilitated wildlife recovery and species reintroductions (Weaver & Skyer, 2003). Conservancies contributed to reclassification of the southwestern black rhino subspecies (*Diceros bicornis occidentialis*) from vulnerable to near threatened by the International Union for Conservation of Nature (Emslie, 2020). Namibia's elephant (*Loxodonta africana*) population increased from about 7,600 to 23,600 during 1995–2016 (Craig et al., 2021) and geographical ranges of lions (*Panthera leo*) and other large carnivores increased (Stander, 2019). Socioeconomic impact from income generation is mixed (Riehl et al., 2015) as conservancies alleviate local poverty (Roe et al., 2013) but benefits can be distributed inequitably (Silva & Mosimane, 2013) or insufficient to compensate costs of human-wildlife conflicts (Kansky, 2022). Inclusive social organization can motivate community participation without income, but non-financial benefits are difficult to measure (Silva & Mosimane, 2014).

A utilitarian approach to conservation assumes that benefits must exceed opportunity costs of traditional uses or livestock alternatives, and that CBNRM program success is related to the quality of natural resources and governance systems (Murphree, 1993). Despite positive social and ecological outcomes from CBNRM (Galvin et al., 2018), there remains a need to evaluate performance as programs evolve (Murphree, 2004). An improved understanding of how the environment interacts with income generation (Cox, 2010) and for CBNRM programs to adopt best governance practices can further conservation (Esmail et al., 2023). Whereas most CBNRM research is qualitative and lacks criteria to assess implementation, income is a direct indicator of financial sustainability (Murphree, 1993). I identified environmental and governance factors influencing income generated by conservancies in Namibia. I evaluated effects of large mammal occurrence and landscape attributes on incomes earned by hunting and photographic tourism during 1998–2022 in Chapter 1. I then evaluated effects of local management and governance performances on total income earned during 2011–2022 in Chapter 2.

CHAPTER 1: DRIVERS OF HUNTING AND PHOTOGRAPHIC TOURISM INCOME TO COMMUNAL CONSERVANCIES IN NAMIBIA

1.1 ABSTRACT

Hunting and photographic tourism provide ecosystem services that can facilitate conservation. Understanding factors influencing how tourism industries generate income is necessary to ensure sustainable community-based natural resource management. I evaluated effects of large mammal occurrence and landscape attributes on incomes from hunting and photographic tourism earned by communal conservancies in Namibia during 1998–2022. I compiled annual incomes and occurrence of 'Big 5' species (elephant [*Loxodonta africana*], buffalo [*Syncerus caffer*], black rhino [*Diceros bicornis*], lion [*Panthera leo*], and leopard [*P. pardus*]) using conservancy accounting and wildlife monitoring data. Hunting occurred in 70 of 86 conservancies and generated income almost twice as rapidly as photographic tourism (2.9 and 5.4 years after conservancy establishment, respectively). Hunting income increased with conservancy area and number of Big 5 species present but decreased with conservancy age and increasing mean elevation, topographic diversity, and distances to national parks. Photographic tourism occurred in 39 conservancies and generated 447% greater median annual income than hunting for conservancies earning >$0. Big 5 species occurrence increased the probability conservancies earned >$0 photographic income but not the amount of photographic income. Photographic income increased with conservancy age and higher annual precipitation but decreased with higher mean elevation. Large mammals are an important driver of income to Namibia's conservancies and hunting and photographic tourism can provide complementary benefits. I recommend Namibia's conservancies, particularly those established more recently with smaller area, consider inter-conservancy wildlife co-management and collaboration with tourism industries to improve income potential and develop more sustainable community-based natural resource economies.

1.2 INTRODUCTION

A utilitarian approach to community-based conservation enables rural people to benefit from wildlife management through payment for ecosystem services (Naidoo et al., 2011a). Sustainable use of wildlife can accelerate development of community-based natural resource management (CBNRM) programs in southern Africa (Frost & Bond, 2008; Weaver et al., 2011).

Tourist hunting provides localized socioeconomic benefits (Jones, 2009) and creates incentives for habitat conservation outside protected areas where there are limited alternative land uses for wildlife (Lindsey et al., 2006, 2007). Nature-based photographic tourism can also provide income to wildlife economies in some areas (WTO, 2014) with potential to support CBNRM's social and environmental objectives when local people are engaged (Mbaiwa & Kolawole, 2013).

Communities that rely on income from hunting and photographic tourism are vulnerable to wildlife trade policies and tourist market instability (Nattrass, 2021a). Importation bans on hunted wildlife are increasingly proposed and adopted in Euro-American jurisdictions (Lindsey et al., 2016). These trade restrictions are often justified morally (Horowitz, 2019) or as solutions to biodiversity loss and sustainability issues, but could adversely affect conservation funding (Di Minin et al., 2016; Dickman et al., 2019) and livelihoods of local communities (Mbaiwa, 2018). Novel zoonotic disease outbreaks also have increased calls to ban wildlife trade (Roe et al., 2020) and contributed to international travel restrictions which present further challenges to tourism that financially jeopardize communities (Hambira et al., 2021; Hulke et al., 2022).

Tourism benefits were volatile during the coronavirus disease 2019 (COVID-19) pandemic, emphasizing a need for improved information on CBNRM economic resiliency and income diversification strategies to reduce financial uncertainties (Lendelvo et al., 2020; Lindsey et al., 2020). Understanding factors that influence income from ecosystem services and implementation of tourism industries are necessary to ensure sustainability of CBNRM (Di Minin et al., 2021). Despite the importance of hunting and photographic tourism to conservation, few studies have investigated environmental drivers of income or compared relative economic performance across large spatial and temporal extents (Suich, 2010; Naidoo et al., 2016).

In Namibia, communal conservancies function as local wildlife governance institutions in a global resource-tourism network (Kalvelage et al., 2020) through leasing tourist concessions and forming joint venture partnerships with operators (Jones et al., 2015). Financial benefits from CBNRM generally increase with program age (Bandyopadhyay et al., 2009; Brooks, 2017), as older conservancies were often established in higher quality wildlife areas and had more time to build capacity, attract business partners, and develop tourist infrastructure (Humavindu & Stage, 2014). Larger conservancies could also benefit from economies of scale employing hunting and photographic tourism operations.

Large mammals, particularly high-value 'Big 5' species (elephant [*Loxodonta africana*], buffalo [*Syncerus caffer*], black rhino [*Diceros bicornis*], lion [*Panthera leo*], and leopard [*P. pardus*]; Di Minin et al., 2013), are an important income source for conservancies (Naidoo et al., 2011b), especially elephant and buffalo that yield high operator fees and hunting quotas on communal lands (Bond, 1994; Arntzen et al., 2003; Naidoo et al., 2016). Hunting fees are critical for funding conservancies' operational expenses (Naidoo et al., 2016) and efficient use of quotas optimizes wildlife-based income (Bollig, 2016). However, environmental factors like drought can reduce wildlife abundance and subsequent quota allocations (NACSO, 2021a). Black rhino and lion presence can increase photographic tourism (Muntifering et al., 2020, 2023a) and conservancies have recently received concessions within Namibia's national parks (MET, 2013), proximity to which could also increase wildlife abundance in nearby conservancies. Additional environmental attributes including topographic diversity and proximity to tourism infrastructure (Nattrass, 2021b; Kalvelage et al., 2021) can improve scenic value and tourist accessibility, respectively (Naidoo et al., 2011b).

I evaluated how incomes from hunting and photographic tourism earned by conservancies in Namibia during 1998–2022 were affected by large mammal occurrence and landscape attributes. I predicted both income sources would increase with years since conservancy establishment and be greater for larger conservancies with more Big 5 species present. I predicted that the number of Big 5 species present would have a stronger positive correlation with hunting income than with photographic income, while photographic income would have a stronger positive correlation with lower and more topographically diverse elevation and proximity to national parks and major roads. Finally, although precipitation can positively affect wildlife occurrence, I predicted that the mean amount of annual precipitation would not be correlated with either income source due to potential resilience of wildlife to drought years and competition with wildlife-based income from alternative land uses (e.g., agriculture, livestock) in conservancies receiving greater precipitation.

1.3 STUDY AREA

Namibia is a large (824,000 km^2) arid to semiarid country in southern Africa with desert to mixed savanna, shrubland, and woodland vegetation (Atlas of Namibia Team, 2022). Annual precipitation ranges from less than 50–650 mm and elevations are 0–2573 m above sea level (Atlas of Namibia Team, 2022). Namibia contains the world's largest free-ranging black rhino population (Muntifering et al., 2023b) and increasing elephant (Craig et al., 2021) and lion populations (Stander, 2019). Protected areas, communally managed wildlife areas, and private freehold lands used for wildlife ranching (Lindsey et al., 2013) combined represent about 46% of Namibia's land area (NACSO, 2021b). Namibia is sparsely populated with 47% of its 2.5 million people living in rural areas with high poverty and unemployment (NSA, 2021; WBG, 2023).

Economic potential for communal areas with high wildlife abundance was recognized in the 1990s (Ashley & Barnes, 1997) after commercialization of wildlife ranching on private lands (Republic of Namibia, 1975). Following Namibia's independence in 1990, progressive land use policies (e.g., MWCT, 1992; MET, 1995) led to the Nature Conservation Amendment Act (Republic of Namibia, 1996) which authorized communities to register customary landholdings as conservancies in 1998. Subsequent legislation enabled conservancy ownership and management of tourism enterprises (Republic of Namibia, 2002; MET, 2007). Conservancies are given conditional property rights and ownership over huntable wildlife and occur primarily in northwestern and northeastern Namibia (Jones, 1999). The conservancy program is managed by the Namibian Association of Community-Based Natural Resource Management Support Organizations (NACSO) and administered by the Ministry of Environment, Forestry and Tourism. The 86 registered conservancies represent about 20% (166,179 km^2) of Namibia's land area and support more than 230,000 people (Figure 1.1; NACSO, 2022a).

1.4 METHODS

I compiled data from NACSO including accounting records collected by conservancies during 1998–2022, years since conservancy establishment, and conservancy area. I used conservancy-led foot patrols, game counts, and wildlife monitoring data from NACSO to index annual occurrence of Big 5 species in each conservancy. I used a digital elevation model (30-m resolution) from the Shuttle Radar Topography Mission (RCMRD, 2017), national park boundaries and trunk roads (major roads for long distance travel) from the Environmental Information Service Namibia eLibrary (EISN, 2020; RAN, 2018), and annual precipitation data (5-km resolution) during 1998–2022 from the United States Geological Survey (Funk et al., 2015). I used conservancy boundaries from NACSO to estimate mean elevation, elevation standard deviation (SD), Euclidean distances to nearest national park border and trunk road, and annual precipitation for each conservancy in ArcGIS Pro (ESRI, 2022). I spatially resampled elevation data to the resolution of annual precipitation data.

I estimated annual hunting income for each conservancy by summing concession and hunting fee payments to respective management committees, salaries earned by conservancy members, direct household payments, and in-kind benefits from hunting operators (i.e., non-financial benefits [e.g., game meat, development projects, donations, training, meals]) included in NACSO's accounting records. I estimated annual photographic income for each conservancy by summing concession fees, salaries earned by conservancy members, direct household payments, and in-kind benefits from photographic operators (excluding game meat). I used values of game meat from hunting operators (excluding conservancy harvest) calculated by NACSO using replacement-cost shadow prices applied nationally each year (Naidoo et al., 2016), which was 27 Namibian dollars (NAD)/kg in 2022 (NACSO, 2023). I standardized all income values to 2022 United States dollars (USD) using the geometrically averaged annual NAD to USD exchange rate (Bank of Namibia, 2023) and USD consumer price index during 1998–2022 (USBLS, 2023). I report median income values due to skewed conservancy income earned from both tourism sources.

I used generalized linear mixed models to evaluate how incomes from hunting and photographic tourism earned by conservancies in Namibia during 1998–2022 were affected by large mammal occurrence and landscape attributes. Distributions for both income sources were zero-inflated and skewed. Therefore, I ran two regression analyses for each income source. I used logistic regression to model a binary response (0 for conservancies earning no income, 1 for conservancies earning >$0 income; Naidoo et al., 2011b) and linear regression to model log-transformed incomes >$0.

I tested for dependence between hunting and photographic incomes using Pearson's product-moment correlation *r* and separate models that included the annual income from the other tourism source as a covariate. I identified a weak positive correlation ($r = 0.08$) between income sources, suggesting limited association. Hunting and photographic incomes were not correlated (95% confidence intervals overlapped 0) when included as covariates in models testing for dependence. I calculated pairwise correlations *r* between continuous covariates and retained only the most relevant in my analyses when $|r| \geq 0.70$ (Dormann et al., 2013).

All final models included fixed-effect covariates for years since conservancy establishment, conservancy area (km^2), annual number of Big 5 species present, mean elevation (m), elevation SD (m), distance to nearest national park (km), distance to nearest major road (km), and annual precipitation (mm) (Table 1.1). I included random intercepts by conservancy to account for repeated annual measurements of the same conservancies across years in all models. I centered and scaled continuous covariates using a standardized z-score normalization (mean = 0, SD = 1). I tested for statistical significance of regression coefficients using $\alpha \leq 0.05$. I visualized regression coefficient estimates and uncertainty using dot-whisker plots with 95% confidence intervals (CI). I performed all analysis in R version 4.2.2 (R Core Team, 2023) using the glmmTMB package for generalized linear mixed models (Brooks et al., 2017) and the DHARMa package for residual diagnostics (Hartig, 2022).

1.5 RESULTS

Median number of years from conservancy establishment through 2022 was 8, median conservancy area was 1167 km^2, and median annual number of Big 5 species present was 1 across conservancies from 1998–2022 (Table 1.1). Leopard had the highest annual mean proportional occurrence among Big 5 species recorded by conservancies ($\overline{p}$ = 0.64), followed by elephant ($\overline{p}$ = 0.37), lion ($\overline{p}$ = 0.35), buffalo ($\overline{p}$ = 0.12), and black rhino ($\overline{p}$ = 0.09). Median mean elevation across conservancies was 1086 m (Table 1.1).

Median hunting income was $26,863 for conservancies earning >$0 annual income ($491,768 maximum, $45,964,012 total; Table 1.2). Hunting occurred in 70 conservancies (141,365 km^2, 85% of total conservancy area; Figure 1.2) and was the dominant (>70% of combined income from both tourism sources) income source in 43 conservancies (78,432 km^2, 47% of total conservancy area; Table 1.2). Median photographic income was $120,081 for conservancies earning >$0 annual income ($1,135,747 maximum, $79,203,315 total; Table 1.2). Photographic tourism occurred in 39 conservancies (81,797 km^2, 49% of total conservancy area; Figure 1.2) and was the dominant (>70% of combined income from both tourism sources) income source in 16 conservancies (49,161 km^2, 30% of total conservancy area; Table 1.2). Neither tourism source represented more than 70% of combined income in 12 conservancies, and 15 conservancies earned no income from either source. Conservancies that earned no income from either tourism source had a median area of 1028 km^2 (12% less than the median area of all conservancies), 6 of which occurred in the northwest Kunene Region. On average, conservancies started earning income from hunting and photographic tourism 2.9 and 5.4 years after establishment, respectively (Table 1.2).

Dispersion of observed binary and nonzero quantile-quantile income values deviated from expected, except for the probability of earning >$0 hunting income (Appendix A). Nonparametric dispersion of the probability of earning >$0 hunting income differed compared to simulated distributions (P = 0.032, Appendix A), but other income types did not. Outlier test plots suggested no model fit issues for income types from either tourism source.

Years since conservancy establishment positively affected the probability conservancies earned >$0 hunting income (ß = 0.66, CI = 0.46–0.86, Figure 1.3a, Appendix B) but conservancy age decreased the amount of hunting income (ß = -0.18, CI = -0.26–-0.10, Figure 1.3b). Increasing median years since conservancy establishment by 5 increased the probability conservancies earned >$0 hunting income from 46% to 60% but decreased the amount of hunting income by $1498 with all other covariates held at median values. The amount of hunting income increased with conservancy area (ß = 0.37, CI = 0.02–0.72, Figure 1.3b) and number of Big 5 species present (ß = 0.28, CI = 0.17–0.38), which also positively affected the probability conservancies earned >$0 hunting income (ß = 0.88, CI = 0.60–1.16, Figure 1.3a). Hunting income increased by $3332 when median conservancy area increased by 2000 km^2 with all other covariates held at median values. Increasing median number of Big 5 species present by 1 and 2 increased the probability conservancies earned >$0 hunting income from 46% to 62% and 77%, respectively, and increased the amount of hunting income by $2399 and $5387, respectively, with all other covariates held at median values. The probability conservancies earned >$0 hunting income and amount of hunting income decreased with increasing mean elevation (ß = -0.33, -0.63–-0.02, Figure 1.3a; ß = -0.53, CI = -1.03–-0.03, Figure 1.3b; respectively). The amount of hunting income also decreased with greater topographic diversity (ß = -0.89, CI = -1.37–-0.41, Figure 1.3b) and distances to nearest national park (ß = -0.43, CI = -0.71–-0.15).

Years since conservancy establishment increased the probability conservancies earned >$0 photographic income and amount of photographic income (ß = 1.19, CI = 0.92–1.46, Figure 1.3c; ß = 0.38, CI = 0.27–0.48, Figure 1.3d; respectively, Appendix B). Photographic income increased by $5627 when median years since conservancy establishment increased by 5 with all other covariates held at median values. Big 5 species occurrence positively affected the probability conservancies earned >$0 photographic income (ß = 0.60, CI = 0.28–0.93, Figure 1.3c) but was not correlated with the amount of photographic income. Increasing median number of Big 5 species present by 1 and 2 increased the probability conservancies earned >$0 photographic income from 2% to 3% and 4%, respectively, with all other covariates held at median values. The probability conservancies earned >$0 photographic income and amount of photographic income decreased with increasing mean elevation (ß = -2.52, CI = -3.54–-1.51, Figure 1.3c; ß = -0.83, CI = -1.24–-0.43, Figure 1.3d; respectively). The amount of photographic income also increased with greater annual precipitation (ß = 0.25, CI = 0.03–0.48, Figure 1.3d).

1.6 DISCUSSION

My predictions on how large mammal occurrence and landscape attributes affected incomes from hunting and photographic tourism earned by conservancies in Namibia during 1998–2022 were partially supported. Conservancy age increased the probability conservancies generated >$0 income from both tourism sources. Conservancy age also had a positive effect on the amount of photographic income, but a negative effect on the amount of hunting income. Larger conservancies generated greater amounts of hunting income, but conservancy area was not correlated with photographic income. Annual occurrence of more Big 5 species increased the probability conservancies generated >$0 income from both tourism sources and the amount of hunting income. That lower mean elevation would be more strongly correlated with photographic income than hunting income was supported, but greater topographic diversity and proximity to national parks were not correlated with photographic income.

The amount of hunting income decreased with conservancy age, which could reflect drought-related quota reductions (NACSO, 2021a), a limited hunting market, or market declines caused by trophy importation issues (Nyamayedenga et al., 2021). That the amount of hunting income increased with larger conservancy area indicates that conservancy size is important for consumptive land use planning. On average, larger conservancies could have more Big 5 species present and potential harvest of other species (e.g., Hartmann's mountain zebra [*Equus zebra hartmannae*], greater kudu [*Tragelaphus strepsiceros*]; Naidoo et al., 2016). Inter-conservancy co-management of wildlife could increase income, particularly for smaller conservancies with less tourism opportunity. For example, the amount of hunting income increased by an equivalent 12% (i.e., $3332) of median hunting income for conservancies earning >$0 annual income when median conservancy area increased by 2000 km^2 (i.e., about the median size of 2 conservancies earning no income from either tourism source, 6 of which occurred in northwest Kunene Region).

The probability conservancies earned >$0 hunting income and amount of hunting income were positively correlated with Big 5 species occurrence, which likely reflected high operator fees paid to conservancies from elephant and buffalo (Naidoo et al., 2016). Greater topographic diversity likely decreased hunter accessibility. The amount of hunting income decreased with greater distances to national parks likely because greater wildlife abundance in national parks increases wildlife abundance in nearby conservancies, supporting the idea that conservancies serve as conservation buffers around protected areas (Meyer et al., 2021).

The probability conservancies earned >$0 photographic income and amount of photographic income increased with conservancy age, which likely reflected development of tourist infrastructure over time and subsequent increases in salaries of conservancy members employed by operators (NACSO, 2021a). The amount of photographic income was not correlated with Big 5 species occurrence despite the importance of black rhino and lion for tourism (Muntifering et al., 2023a; NACSO, 2023). Photographic tourism could offer income alternatives for Namibia's conservancies without Big 5 species present despite international tourists' interest in primarily viewing large mammals (Di Minin et al., 2013).

Conservancies with lower mean elevation earned more income, particularly from photographic tourism, which could reflect that conservancies established earlier occurred in lower elevation areas with higher tourist accessibility or habitat quality for Big 5 species. Greater topographic diversity was not correlated with photographic income despite possible improved scenic value and mountainous terrain on popular tourism circuits (Naidoo et al., 2011b). The spatial resolution of elevation SD also could have been too coarse to reflect local variation in conservancy elevation. That photographic income was not correlated with proximity to national parks (e.g., Etosha National Park) suggests that any recently awarded concessions are not yet operational. For example, 23 conservancies shared 19 concessions in national parks in 2020 (NACSO, 2021a), but photographic tourism started generating income after 5 years on average. I was unable to assess income earned by these specific concessions, but they could be expected to generate photographic income soon. Conservancies adjacent to national parks earned less income from photographic tourism than the median income of conservancies generating income from this source.

Large mammals remain an important driver of ecosystem services to Namibia's conservancies (Naidoo et al., 2011b), although community benefits can be reduced by associated human-wildlife conflicts (Carpenter, 2022; Tavolaro et al., 2022). My data for recording annual Big 5 species occurrence provides an index of large mammal occurrence including other species that could increase tourism (e.g., giraffe [*Giraffa camelopardalsi*], hippopotamus [*Hippopotamus amphibius*]). Namibia's conservancy-led monitoring system could be used to encourage additional conservation investment by further demonstrating biodiversity occurrence to the private sector and donors (Stuart-Hill et al., 2005). This monitoring system is also used to establish quotas and manage harvests with the Ministry of Environment, Forestry and Tourism. Conservancies used only 37% of their total quota for huntable Big 5 species (excluding black rhino) during 2006–2022 (NACSO, unpublished data). More efficient quota use could increase hunting income, assuming quotas are sustainable and there is adequate hunting demand.

Hunting and photographic tourism in Namibia appear to be complementary ecosystem services (Naidoo et al., 2016). While income from photographic tourism could equal or exceed income from hunting (e.g., 447% greater median annual income for conservancies earning >$0, 172% greater total income across conservancies during 1998–2022), income from hunting occurred in more conservancies and generated income more rapidly, suggesting that hunting cannot be easily replaced. Previous analysis simulating a tourist hunting ban revealed negative impacts to conservancy operational budgets (Naidoo et al., 2016; NACSO, 2021a). While there is unlikely a risk of a tourist hunting ban considering that Namibia's domestic policy supports sustainable use of wildlife (Republic of Namibia, 1990; cf., Botswana during 2014–2019; Mbaiwa, 2018), importation restrictions on hunted wildlife in consumer countries can reduce community benefits from lower hunter visitation, spending, and quota use (Nyamayedenga et al., 2021). For example, the United States Fish & Wildlife Service's elephant import permitting has been subject to litigation for economic harm to Namibia's conservancies (*DSC vs. Bernhardt*, 2021). Namibia's conservancies are especially susceptible to wildlife importation policy in the United States given reliance on American hunters targeting high-value species (e.g., elephant; MacLaren et al., 2019). Importation restrictions on hunted wildlife could threaten livelihoods and habitat conserved by Namibia's conservancies (MacLaren et al., 2019), along with similar CBNRM programs in southern Africa (e.g., Communal Areas Management Program for Indigenous Resources Association in Zimbabwe; MECTHI, 2023), unless alternatives to hunting are available (White & Belant, 2015).

Community benefits from tourist hunting also depend on effective international regulation of wildlife trade (e.g., Convention on International Trade in Endangered Species of Wild Fauna and Flora; Abensperg-Traun, 2009; Carpenter, 2011; Cooney et al., 2021). Hunting could be more resilient than photographic tourism to global market dynamics (e.g., COVID-19 pandemic; MEFT, 2021; 2008 Great Recession; Naidoo et al., 2016) and has widespread support from Namibia's conservancies (Angula et al., 2018), which have more positive attitudes toward wildlife when benefiting from hunting (Störmer et al., 2019). Wildlife trade policies that consider potential impacts to indigenous people and local communities could improve benefits from tourist hunting (Houdt et al., 2021; Clark et al., 2023; Challender et al., 2023).

Income varied markedly across conservancies in Namibia and is dominated by hunting and photographic tourism (estimated 97% of total income, excluding grants, across conservancies in 2022; NACSO, unpublished data), compared to other activities available (e.g., plant harvesting [e.g., Devil's claw {*Harpophytum spp.*}; Lavelle, 2023], craft sales). Conservancies' reliance on hunting and photographic tourism suggest diversification strategies could improve income potential by including development of additional tourist markets (MacLaren et al, 2019; MEFT, 2021), mixed agriculture production (e.g., small-scale horticulture; Hulke et al., 2021), and carbon or biodiversity credits (Smith et al., 2022), which are being developed in some of Namibia's conservancies (NACSO, 2023). Namibia had 46 community forests and 20 fishery reserves shared by 7 conservancies in 2022 (NACSO, 2023), which can generate income from sale of natural plant products (e.g., timber, Devil's claw) and fishing tourism. Wildlife-based income on communal lands could also be improved through higher tourist willingness to pay for conservation and community benefits (Fischer et al., 2015; Naidoo et al., 2021), direct community participation in the private sector (e.g., negotiating quota price; Rigava et al., 2006; marketing; Child & Weaver, 2006; shared business ownership models; Hoole, 2009), national investment in sustainable tourism (MET, 2016), and strengthening governance (Child & Barnes, 2010; Ullah & Kim, 2020).

Financial sustainability is critical to building resilient community-based natural resource economies. My results support the development of emerging conservancies in Namibia's northeast Zambezi Region that have high tourism potential from Big 5 species presence, low elevations, and high annual precipitation (NACSO, 2021a). I recommend that Namibia's conservancies, particularly those established more recently, with smaller area, and adjacent to other conservancies (e.g., northwest Kunene Region), consider implementing inter-conservancy wildlife co-management or shared land use zonation plans and collaborate with tourism industries to improve income potential from hunting and photographic tourism.

TABLES & FIGURES

Table 1.1: Variables potentially affecting hunting and photographic tourism income earned by communal conservancies in Namibia, 1998–2022.

Variable	**Median**	**Range**
Years since establishment	8	0–24
Area (km^2)	1167	43–9122
Annual Big 5 species occurrence	1	0–5
Mean elevation (m)	1086	600–1624
Elevation SD (m)	70	0–327
Distance to nearest national park (km)	38	0–230
Distance to nearest major road (km)	83	0–320
Annual precipitation (mm)	241	31–1037

Table 1.2: Summary of annual income estimates (2022 United States dollars) from hunting and photographic tourism earned by communal conservancies in Namibia, 1998–2022.

Statistic	**Hunting**	**Photographic Tourism**
Mean	$32,622	$56,212
Median income >$0	$26,863	$120,081
Maximum	$491,768	$1,135,747
Total	$45,964,012	$79,203,315
Conservancies earning income >$0	70	39
Area (km^2) earning income >$0	141,365	81,797
Percent total area earning income >$0	85	49
Conservancies by dominant income source (>70% of combined income from both tourism sources)	43	16
Area (km^2) by dominant income source	78,432	49,161
Percent total area by dominant income source	47	30
Average years from conservancy establishment to initial income	2.9	5.4

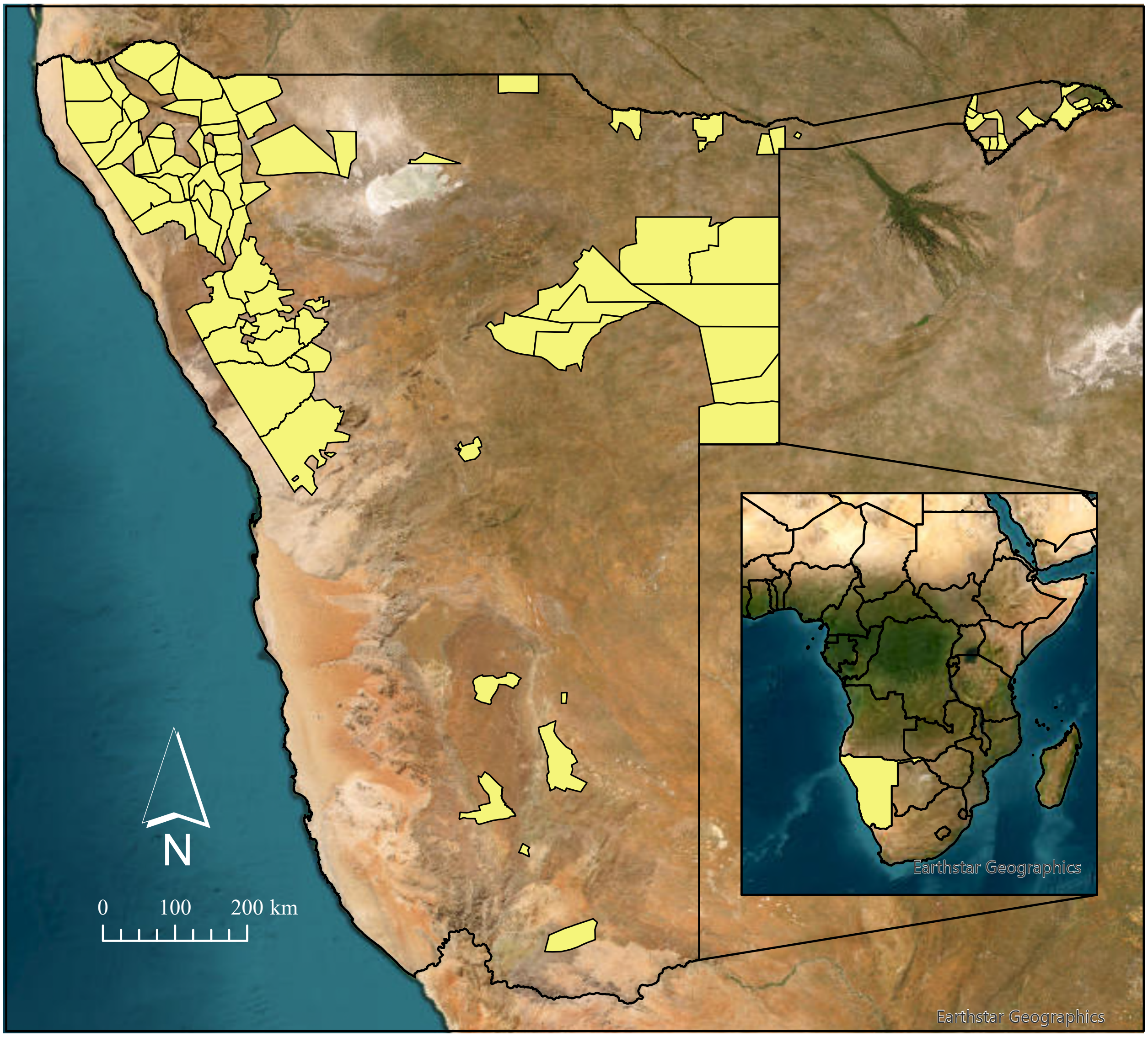

Figure 1.1: Communal conservancies (yellow polygons) in Namibia, 2022 (NACSO).

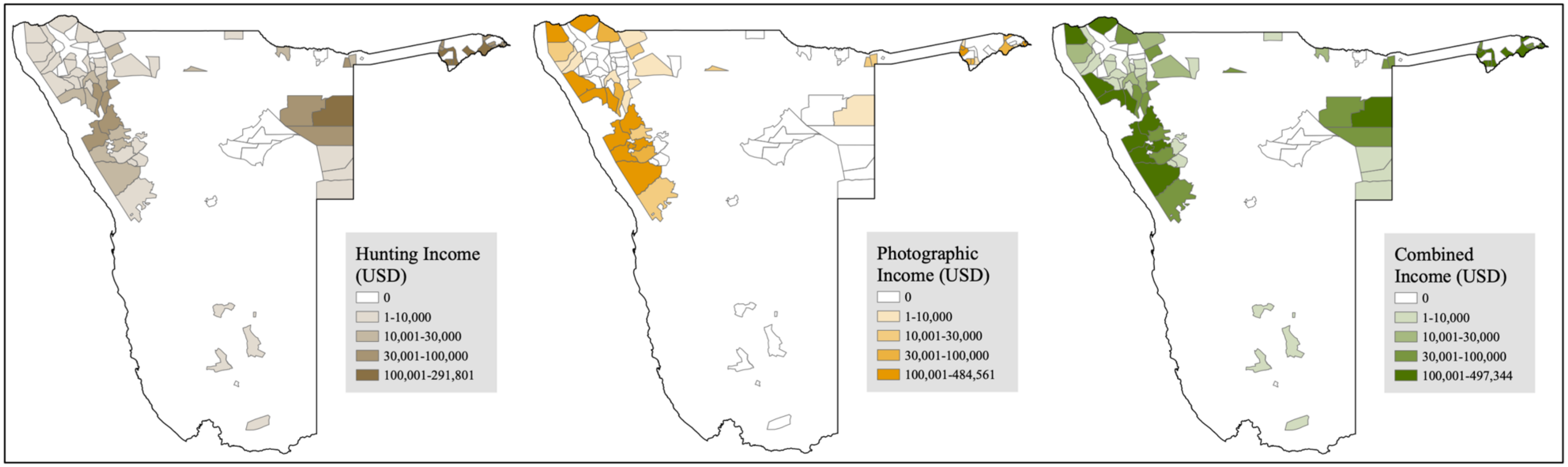

Figure 1.2: Annual mean income from hunting, photographic tourism, and combined income from both sources earned by communal conservancies in Namibia, 1998–2022.

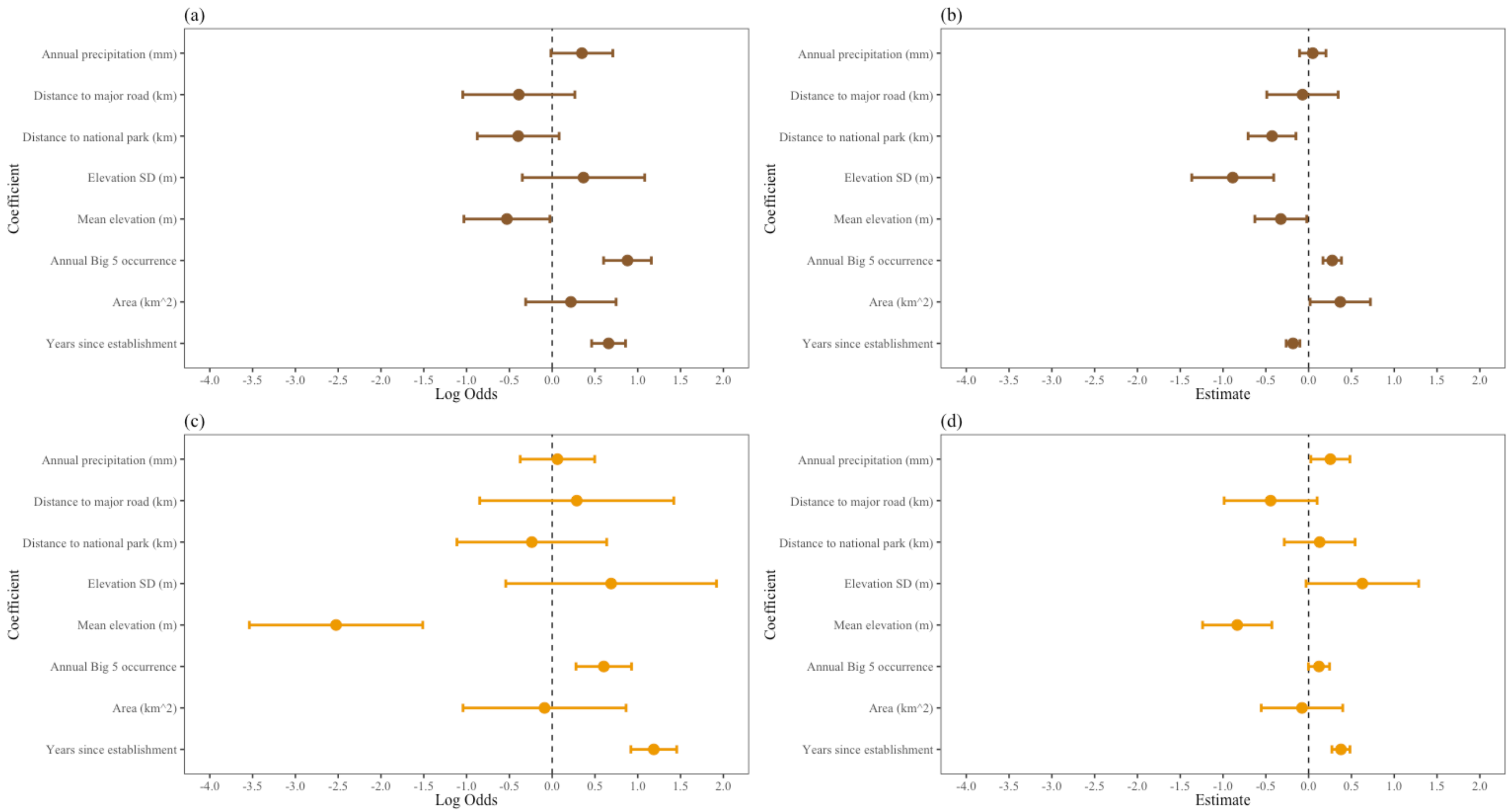

Figure 1.3: Standardized regression coefficient estimates with 95% confidence intervals (i.e., whiskers) for generalized linear mixed models fit to the (a) probability of earning >$0 hunting income, (b) amount of hunting income, (c) probability of earning >$0 photographic income, and (d) amount of photographic income earned by communal conservancies in Namibia, 1998–2022.

CHAPTER 2: LOCAL MANAGEMENT AND GOVERNANCE IMPROVE NATURAL RESOURCE INCOMES OF COMMUNAL CONSERVANCIES IN NAMIBIA

2.1 ABSTRACT

Governance of communal institutions is critical to the financial sustainability of community-based natural resource management economies. I evaluated effects of local management and governance on income earned by communal conservancies in Namibia during 2011–2022. I compiled annual income and performance scores for natural resource management and institutional governance using conservancy accounting and ‘event book’ monitoring data (governance performance collected since 2019). Conservancies earning >$0 income generated a median annual of $60,518 since 2011 and $50,283 since 2019 (17% less than during 2011–2022). Income increased with years since conservancy establishment, higher management performance which also positively affected the probability conservancies earned >$0 income, presence of nongovernmental organization (NGO) support within conservancies, and annual general meeting (AGM) occurrence. Income earned during 2019–2022 also increased with higher governance performance. Median management and governance performances across conservancies were only about 50% of their maximum scores, indicating higher income potential with improved performance. Conservancies remained financially dependent on NGO support and AGMs were important functions for generating income. Natural resource management and institutional governance facilitated income generation by Namibia’s conservancies, but more investment in benefit distribution could increase socioeconomic impact. I recommend that Namibia’s conservancies, particularly those established more recently or without NGO presence, prioritize improving local management and governance to develop more sustainable community-based natural resource economies.

2.2 INTRODUCTION

Indigenous-led governance of communal lands is considered necessary for effective and socially just conservation (Artelle et al., 2019). Community-based natural resource management (CBNRM) is a democratic approach to governance based on devolution of land use rights from government to local levels (Smith, 2019), decentralized management authority (Ribot, 2002), and shared decision-making (Child, 2019). Benefits generated from ecosystem services (e.g., hunting and photographic tourism; Goergen et al., unpublished data), however, are not passively converted into conservation outcomes by indigenous peoples or local communities (Child & Barnes, 2010). Developing communal institutions (Agrawal & Gibson, 1999) and adaptive management (Barnes & Child, 2014) are necessary to administer finances and provide incentives for participation in coupled human-natural systems (Ostrom, 2010). Benefit distribution also can be a critical governance challenge for CBNRM (Silva & Mosimane, 2013).

In southern Africa, rapid income generation from sustainable wildlife use (Weaver et al., 2011) necessitates local financial management with community engagement and leadership accountability (Child & Barnes, 2010). Benefits from CBNRM programs (e.g., Communal Areas Management Program for Indigenous Resources Association in Zimbabwe; Taylor, 2009) can be greater than costs of developing communal institutions when distribution is equitable and transparent (Child et al., 2014). While empowerment from inclusive social organization (Silva & Mosimane, 2014) can provide conservation incentives without financial benefits (Ashley, 1998), income is invested in management capacity and generates community interest in benefit distribution which can reduce corruption (Jones et al., 2015). Income potential improves with more effective governance (Chidakel & Child, 2022) as community participation increases accountability (Child, 2006), conservation practices are accepted (Ostrom, 2000), and investments from the private sector (Lapeyre, 2011) or nongovernmental organizations (NGO) increase (Lindsey et al., 2014).

International policies and multilateral environmental agreements (Larson et al., 2022) increasingly recognize the importance of indigenous peoples and local communities to conservation (e.g., Convention on Biological Diversity; Reyes-García et al., 2022). Despite this global support (Garnett et al., 2018), along with concern for socioeconomic impacts of CBNRM (Fariss et al., 2022) and programmatic focus on improving governance (NACSO, 2022a), quantitative information on performance of communal institutions is limited (Zhang et al., 2023) and existing community-led monitoring data is underused (Collomb et al., 2010). Less income generated from tourism and social gathering restrictions during the coronavirus disease 2019 (COVID-19) pandemic (Lindsey et al., 2020) also emphasized need for resilient communal institutions (Hulke et al., 2022).

Namibia's communal conservancies monitor natural resource management and institutional governance annually to assess programmatic efficacy (NACSO, 2023). Income from CBNRM generally increases with program age (Bandyopadhyay et al., 2009), as older conservancies have more mature management capacity (Brooks, 2017), implement best governance practices, and facilitate private sector or NGO investments (Humavindu & Stage, 2014). Conservancies employ staff that manage natural resources (e.g., community game guards) and are governed by elected committees. Performances of conservancy staff in natural resource management and committees in institutional governance are reported separately using indicators with categorical ratings (Stuart-Hill et al., 2005). Support NGOs (e.g., Integrated Rural Development and Nature Conservation) facilitated development of Namibia's conservancy program in the late 1990s and can assist with natural resource management, private sector negotiations, and securing grants (Kalvelage et al., 2020). Annual general meetings (AGM) provide opportunities for conservancy members to engage directly in decision-making, especially financial management, and with tourism operators or NGOs (Muyengwa, 2015) but participation can be limited (Collomb et al., 2010).

I evaluated effects of local management and governance on income earned by conservancies in Namibia during 2011–2022. I predicted that income would increase with years since conservancy establishment, higher management performance scores, NGO presence, and AGM occurrence. I predicted that income would also increase with higher governance performance scores during 2019–2022 despite less income earned and challenges to conservancy operations during the COVID-19 pandemic (i.e., 2020–2021) (Lendelvo et al., 2020).

2.3 STUDY AREA

Namibia is a sparsely populated country in southern Africa (824,000 km^2; Atlas of Namibia Team, 2022) with 47% of its 2.5 million people living in rural areas with high poverty and unemployment (NSA, 2021; WBG, 2023). Protected areas, communally managed wildlife areas, and private freehold lands used for wildlife ranching (Lindsey et al., 2013) combined represent about 46% of Namibia's land area (NACSO, 2021a). Economic potential for communal areas with high wildlife abundance was recognized in the 1990s (Ashley & Barnes, 1997) after commercialization of wildlife ranching on private lands (Republic of Namibia, 1975). Following Namibia's independence in 1990, progressive land use policies (e.g., MWCT, 1992; MET, 1995) led to the Nature Conservation Amendment Act (Republic of Namibia, 1996), which authorized communities to register customary landholdings as conservancies in 1998. Subsequent legislation enabled conservancy ownership and management of tourism enterprises (Republic of Namibia, 2002; MET, 2007).

Conservancies are local natural resource management institutions with conditional property rights and reporting requirements (e.g., constitution, zonation, wildlife management and benefit distribution plans) to the Ministry of Environment, Forestry and Tourism (MEFT) (Jones, 1999). Namibia's conservancies are recognized globally as a leading CBNRM program (Jones, 2010) enabled by support from NGOs and land use rights legislated by the national government (Boudreaux & Nelson, 2011). The conservancy program is managed by the Namibian Association of Community-Based Natural Resource Management Support Organizations (NACSO) and administered by MEFT. The 86 registered conservancies represent about 20% (166,179 km^2) of Namibia's land area and support more than 230,000 people (Figure 2.1; NACSO, 2022b).

2.4 METHODS

I compiled data from NACSO including accounting records collected by conservancies during 1998–2022, years since conservancy establishment, and annual presence of NGO support within conservancies. I used conservancies' annual monitoring data collected during 2011–2022 from NACSO to compile management performance, governance performance (collected since 2019), and AGM occurrence for each conservancy that used NACSO's 'event book' monitoring tool (Stuart-Hill et al., 2005).

I estimated total income earned by each conservancy annually during 2011–2022 by summing concession and hunting fee payments to respective governing committees, salaries earned by conservancy members, direct household payments, and in-kind non-financial benefits (e.g., game meat, development projects, training, meals) from tourism operators. I added income from small- to medium-sized businesses (e.g., plant harvesting [e.g., Devil's claw {*Harpophytum spp.*}; Lavelle, 2023], craft sales), game meat from conservancy harvests, grants, donations, bank interest, and other miscellaneous sources included in NACSO's accounting records. I used game meat values calculated by NACSO using replacement-cost shadow prices applied nationally each year (Naidoo et al., 2016), which was 27 Namibian dollars (NAD)/kg in 2022 (NACSO, 2023). I standardized all income values to 2022 United States dollars (USD) using the geometrically averaged annual NAD to USD exchange rate (Bank of Namibia, 2023) and USD consumer price index during 2011–2022 (USBLS, 2023). I report median income values due to skewed distribution of income across conservancies.

Performances of conservancy staff in natural resource management and committees in institutional governance are reported separately in event books. I compiled annual management performance scores for each conservancy during 2011–2022 using categorical ratings of 16 indicators assessing conservancy commitment to, planning or monitoring of, and benefits from natural resource management activities (Appendix C). I excluded other indicators due to missing data (i.e., harvest management) or because they did not directly assess performance of conservancy staff (i.e., wildlife population trends and status). Categorical ratings were 0–2 to 0–6 depending on the indicator. Therefore, I scaled all ratings to 1 to treat each indicator equally. I summed all ratings to derive an overall management performance score of 16 maximum points for each conservancy annually, and I assumed equal importance among indicators as each was similarly prioritized by NACSO (Figure 2.2). Data were missing from 15 conservancies that did not use event books to report management performance and other conservancies that did not report ratings for every indicator each year (Table 2.1).

I compiled annual governance performance scores for each conservancy during 2019–2022 using categorical ratings of 6 indicators including member engagement, transparent and participatory benefit planning, equitable benefit distribution, committee accountability, external stakeholder engagement, and financial management. I excluded an indicator for compliance with MEFT requirements due to missing data. Categorical ratings for all indicators ranged from 0 to 5 (i.e., NA, none, weak, moderate, strong, and exceptional, respectively). I scaled all ratings to 1 to treat each indicator equally based on their inclusion as performance metrics. I summed all ratings to derive an overall governance performance score of 6 maximum points for each conservancy annually, again assuming indicators were equally important as prioritized by NACSO (Figure 2.2).

I used generalized linear mixed models to evaluate effects of local management and governance on income earned by conservancies in Namibia. I conducted two analyses during 2011–2022 and 2019–2022 to account for different data domains (governance performance collected since 2019, Table 2.1). As distributions of conservancy incomes were zero-inflated and skewed, I ran two regression models for each analysis. I used linear regression to model log-transformed incomes >$0 and logistic regression to model a binary response (0 for conservancies earning no income, 1 for conservancies earning >$0 income; Naidoo et al., 2011b). Both models included fixed-effect covariates for years since conservancy establishment, annual management performance, annual NGO presence (0 or 1), and AGM occurrence (0 or 1) (Table 2.1). In the second analysis, I used the same modeling approach but used only the subset of data during 2019–2022 when governance performance was collected. Model structures were identical to the previous analysis, except I also included a covariate for annual governance performance.

For all models, I included random intercepts by conservancy to account for repeated annual measurements of the same conservancies across years. I calculated pairwise correlations r between continuous covariates and retained the most relevant for analyses when $|r| \geq 0.70$ (Dormann et al., 2013). I centered and scaled continuous covariates using a standardized z-score normalization (mean = 0, standard deviation = 1). I tested for statistical significance of regression coefficients using $\alpha \leq 0.05$. I visualized regression coefficient estimates and uncertainty using dot-whisker plots with 95% confidence intervals (CI). I performed all analysis in R version 4.2.2 (R Core Team, 2023) using the glmmTMB package for generalized linear mixed models (Brooks et al., 2017) and the DHARMa package for residual diagnostics (Hartig, 2022).

2.5 RESULTS

Median number of years from conservancy establishment through 2022 was 10 since 2011 and 15 since 2019 (Table 2.1). Median annual management performance score across conservancies was 7.4 during 2011–2022 (Table 2.1) and 4.8 for 19 conservancies without an NGO present (maximum of 16). Median annual governance performance score was 3.2 (maximum of 6; Table 2.1). The proportion of conservancies across years with an NGO present was 0.76 and with an AGM was 0.69 during 2011–2022.

Median annual income for conservancies earning >$0 was $60,518 ($1,368,827 maximum, $111,928,397 total) during 2011–2022 and $50,283 ($1,022,904 maximum) during 2019–2022 (Table 2.2). Median annual income for 19 conservancies without an NGO present when earning >$0 was $4638 during 2011–2022 and $6808 during 2019–2022 (i.e., 8% and 14%, respectively, of median annual income for conservancies earning >$0; Table 2.2). All 86 conservancies earned at least some income since 2011, but 2 conservancies did not earn income since 2019 (Table 2.2). Since 1998, conservancies on average generated income 1.8 years after establishment.

Models for 2011–2022, management only

Residual diagnostics showed no model fit issues except that dispersion of observed quantile-quantile values deviated from expected for nonzero incomes during 2011–2022 (Appendix D). Years since conservancy establishment positively affected the amount of income (ß = 0.12, CI = 0.01–0.23, Figure 2.3a, Appendix E) with a median increase of 5 years across conservancies resulting in an increase of $4551, holding all other covariates at median values. Annual management performance positively affected the amount of income (ß = 0.31, CI = 0.17–0.45, Figure 2.3a) with a median increase from 7.4 to 16 (i.e., maximum score) across conservancies resulting in an increase of $89,581 (i.e., 148% of median annual income for conservancies earning >$0), holding all other covariates at median values. Annual management performance also positively affected the probability conservancies earned >$0 income (ß = 2.37, CI = 1.75–2.99, Figure 2.3b). Annual NGO presence positively affected the amount of income (ß = 1.43, CI = 0.43–2.43, Figure 2.3a) with a median decrease to 0 NGO presence across conservancies resulting in a decrease of $29,240 (i.e., 48% of median annual income for conservancies earning >$0), holding all other covariates at median values. Occurrence of AGMs also positively affected the amount of income (ß = 0.31, CI = 0.13–0.49, Figure 2.3a) with a median decrease to 0 AGM occurrence across conservancies resulting in a decrease of $10,286, holding all other covariates at median values.

Models for 2019–2022, management and governance

Years since conservancy establishment positively affected the amount of income (ß = 0.63, CI = 0.37–0.90, Figure 2.3c, Table E.2) with a median increase of 5 years across conservancies resulting in an increase of $43,864, holding all other covariates at median values. Annual governance performance positively affected the amount of income (ß = 0.24, CI = 0.10–0.37, Figure 2.3c) with a median increase from 3.2 to 6 (i.e., maximum score) across conservancies resulting in an increase of $86,251 (i.e., 172% of median annual income for conservancies earing >$0), holding all other covariates at median values. Annual management performance positively affected the probability conservancies earned >$0 income (ß = 1.80, CI = 0.92–2.68, Figure 2.3d) but not the amount of income. Annual NGO presence positively affected the amount of income (ß = 1.13, CI = 0.28–1.97, Figure 2.3c) with a median decrease to 0 NGO presence across conservancies resulting in a decrease of $34,515 (i.e., 69% of median annual income for conservancies earning >$0), holding all other covariates at median values.

Occurrence of AGMs was not correlated with income during 2019–2022 when annual governance performance was included.

2.6 DISCUSSION

My predictions that income earned by conservancies in Namibia during 2011–2022 and 2019–2022 was affected by local management and governance were supported. The probability conservancies earned >$0 income was positively affected by management performance, but other covariates had no effect, likely because most conservancies earned >$0 income annually since 2011 regardless of NGO presence, AGM occurrence, or age. Conservancy age increased income, which likely reflected improved management and governance performance over time. That conservancy age increased income could also indicate that older conservancies were established in higher quality wildlife areas, which facilitated tourism or NGO investments (Goergen et al., unpublished data).

Management performance positively affected the amount of income and probability conservancies earned >$0 income, and governance performance also increased the amount of income earned during 2019–2022. That management performance was not correlated with the amount of income earned during 2019–2022 indicates that income depended more on conservancy age, governance performance, and NGO presence in more recent years or was influenced by missing data in management performance. Management performance also could be correlated with wildlife-based income potential from ecosystem services (Goergen et al., unpublished data), but governance performance was more important for increasing income earned from natural resources (Kalvelage et al., 2020). Income increased by an equivalent of 148% (i.e., $89,581) or 172% (i.e., $86,251) of median annual income for conservancies earning >$0 when median annual management or governance performance increased to maximum scores since 2011 and 2019, respectively. That median annual management and governance performances across conservancies were only about 50% of their maximum scores (30% of management performance for conservancies without an NGO present) indicates higher income potential with improved performance.

Presence of an NGO was associated with greater income, which likely reflected natural resource management assistance or grants provided by NGOs. Despite potential for financial sustainability through ecosystem services (Barnes et al., 2002), conservancies remained dependent on NGO support. However, NGOs rely on philanthropic funding that could represent external interests misaligned with conservancy priorities (e.g., wildlife conservation vs. benefit distribution; Crosman et al., 2021). More transparent partnerships with conservancies (Buzzard et al., 2023) and NGO assistance in institutional development could increase governance performance for low scoring indicators (i.e., benefit planning, benefit distribution, financial management). I suggest expanding NGO support to other conservancies through new partnerships, especially for conservancies earning less income and with lower performance scores (e.g., northwest Kunene Region).

Occurrence of AGMs was associated with greater income earned since 2011 but not since 2019, which likely reflected less AGMs during the COVID-19 pandemic (i.e., 60% of conservancies that reported had no AGM in 2020; NACSO, 2021b). That AGMs positively affected the amount of income earned during 2011–2022 indicates that AGMs are important functions for conservancies (Muyengwa, 2015). That AGM occurrence recovered quickly after the COVID-19 pandemic (i.e., 87% of conservancies that reported had an AGM in 2021; NACSO, 2022b) also emphasized their importance to conservancy governance. However, conservancy members' trust in governing committees to administer finances can be low (B. Child et al., unpublished data), suggesting that AGMs could be restructured to increase participation and governance performance for member engagement and committee accountability indicators (Shimansky, 2021).

Local management and governance facilitate income by Namibia's conservancies (Lapeyre, 2015). Median annual income for conservancies earning >$0 during 2019–2022 was 17% (i.e., $10,235) less than during 2011–2022, despite an increase in grants (e.g., COVID-19 pandemic emergency relief funding), but I expect income to recover from the COVID-19 pandemic as tourism increases (NACSO, 2022b). Number of natural resource-based income sources had the lowest median score (i.e., 0.17) among management performance indicators, indicating need for diversification (Naidoo et al., 2011a). Income generation can also improve with direct participation of indigenous peoples and local communities in tourism industries (e.g., shared business ownership models; Hoole, 2009) or international wildlife trade policy (e.g., Convention on International Trade in Endangered Species of Wild Fauna and Flora; Roe et al., 2022).

Financial sustainability is critical to building CBNRM economies that are resilient to climate-changed induced drought (Carpenter, 2022), increasing costs of human-wildlife conflicts

(Schnegg & Kiaka, 2018), and tourism market dynamics (e.g., wildlife trade restrictions; Nyamayedenga et al., 2021). Benefit distribution had the lowest median score (i.e., 0.4) among governance performance indicators but increases participation in CBNRM (Merz et al., 2023). In 2022, only 7 conservancies met MEFT's requirement to invest at least 50% of income in community development (NACSO, 2023) and compensation for human-wildlife conflicts represented 47% of cash benefits to conservancy members (NACSO, 2023). While human-wildlife conflict compensation is an important social service (Tavolaro et al., 2022), it diverts spending from income generating opportunities or more transformative community development (B. Child et al., unpublished data). Continued emphasis on equitable benefit distribution and more effective conservancy spending could increase the socioeconomic impact of income generated (Mosimane & Silva, 2015).

Namibia's event books are an effective community-led monitoring system used to assess conservancy performance as natural resource management institutions (Stuart-Hill et al., 2005). Missing data precluded analysis of factors including conservancy compliance with MEFT requirements or gender equality of committees and staff, priorities for NACSO (NACSO, 2022a). In addition, some NGOs that work in Namibia's conservancies (e.g., World Wildlife Fund Namibia) were not included in the data. Increasing the number of conservancies using event books and overall data reporting quality could improve future research. Event books can also be used to monitor poaching or human-wildlife conflicts (Wenborn et al., 2022) but some data could be socially constructed (Lubilo & Hebinck, 2019) and confirmed by additional data collection.

Namibia's national level legislation and NGO support enabled effective governance (Nelson et al., 2021) relative to CBNRM programs in other countries (Child & Barnes, 2010). However, secure land tenure can limit development of CBNRM (Nelson & Agrawal, 2008) and its contributions to indigenous peoples' rights (e.g., Khoi and San peoples; Anaya, 2013). Representative committees, while an effective governing structure for Namibia's conservancies (Child et al., 2014), might not be applicable to communal institutions elsewhere in southern Africa (Mavah et al., 2022).

Improvements in natural resource management and institutional governance can greatly increase income for CBNRM economies. My results support the development of emerging conservancies in Namibia's northeast Zambezi Region that have high income potential from high management and governance performances and NGO presence (NACSO, 2021b). I recommend that Namibia's conservancies, particularly those established more recently or without NGO presence (e.g., northwest Kunene Region), prioritize improving local management and governance to develop more resilient communal institutions that are financially sustainable.

TABLES & FIGURES

Table 2.1: Variables potentially affecting incomes earned by communal conservancies in Namibia, 2011–2022 and 2019–2022.

	2011–2022			2019–2022		
Variable	**Median**	**Range**	**NAs**	**Median**	**Range**	**NAs**
Years since establishment	10	0–24	-	15	1–24	-
Annual management performance (maximum score of 16)	7.4	0.2–11.8	227	7.8	1.1–11.8	76
Annual governance performance (maximum score of 6)	-	-	-	3.2	1.6–4.6	24
Annual nongovernmental organization presence	1	0–1	63	1	0–1	15
Annual general meeting occurrence	1	0–1	113	1	0–1	21

Table 2.2: Summary of annual income estimates (in 2022 United States dollars) earned by communal conservancies in Namibia, 2011–2022 and 2019–2022.

Statistic	**2011–2022**	**2019–2022**
Mean	$114,096	$104,270
Median income >$0	$60,518	$50,283
Maximum	$1,368,827	$1,022,904
Total	$111,928,397	$35,868,952
Conservancies earning income >$0	86	84
Median income >$0 for conservancies without a nongovernmental organization present (19)	$4638	$6808

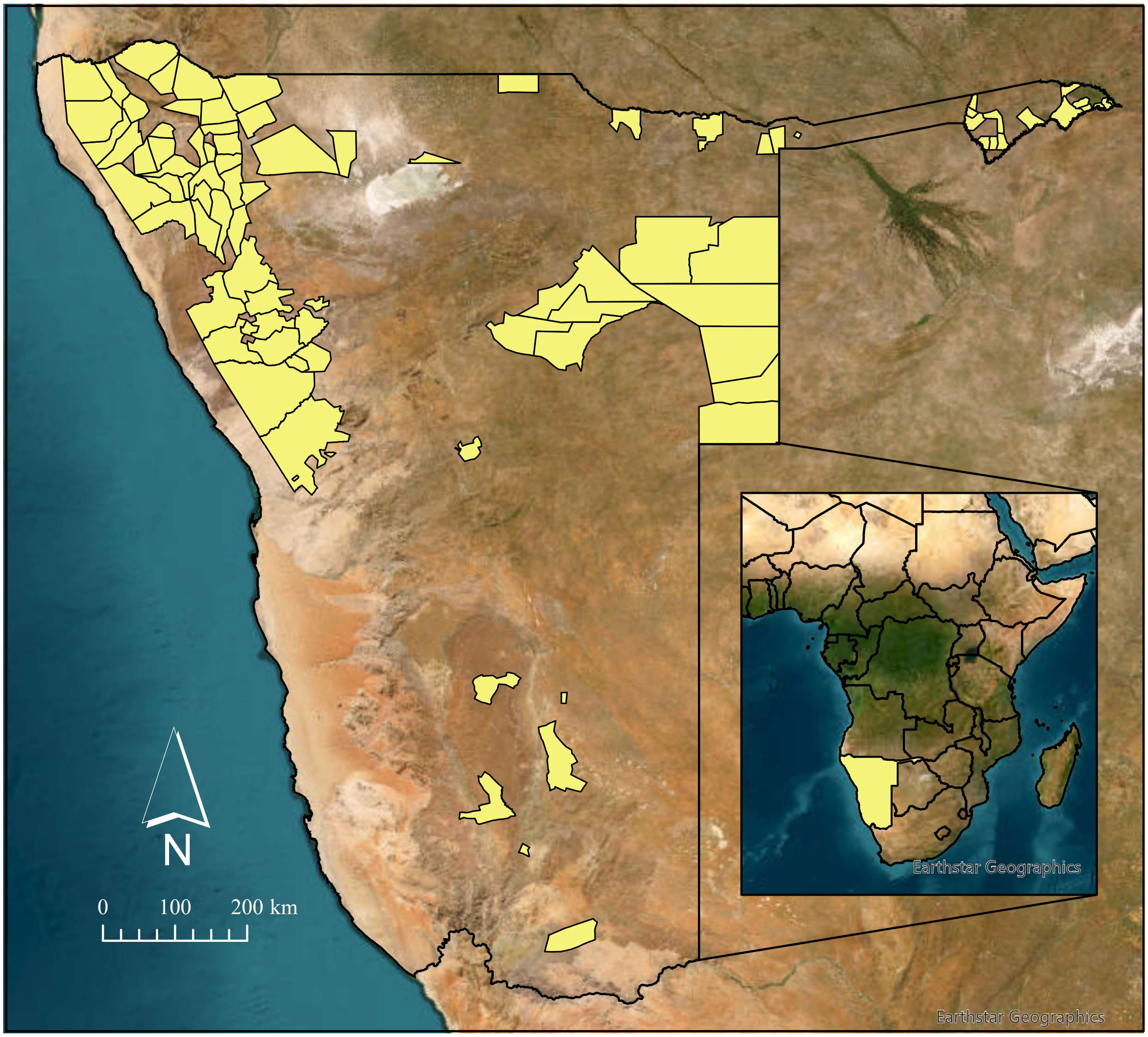

Figure 2.1: Communal conservancies (yellow polygons) in Namibia, 2022 (NACSO).

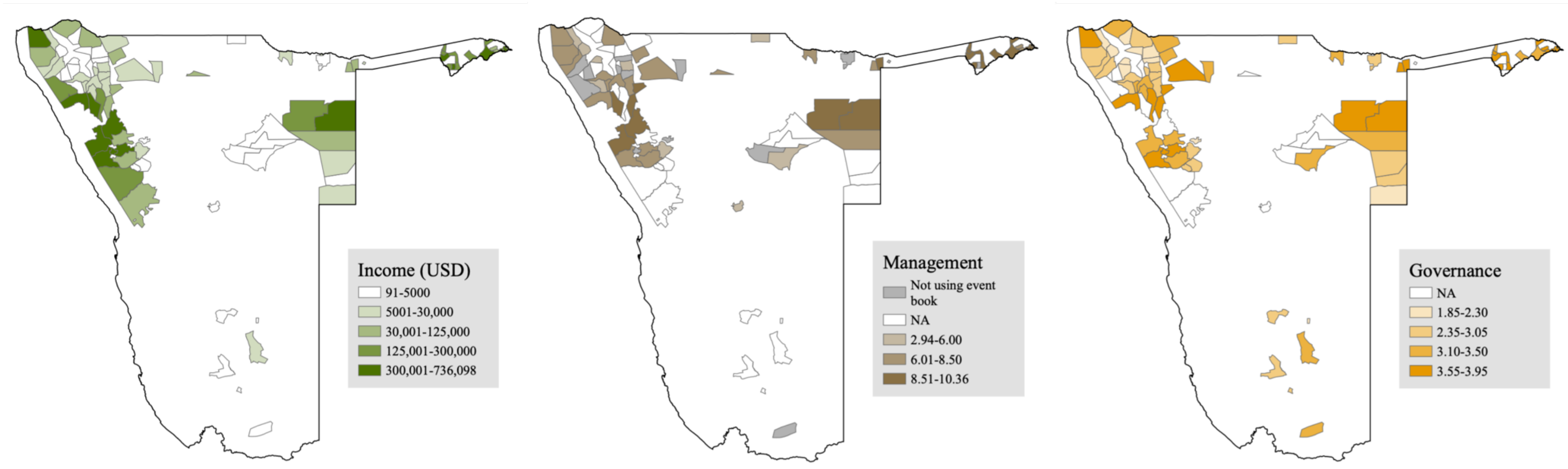

Figure 2.2: Annual mean income, management performance, and governance performance (2019–2022) of communal conservancies in Namibia, 2011–2022.

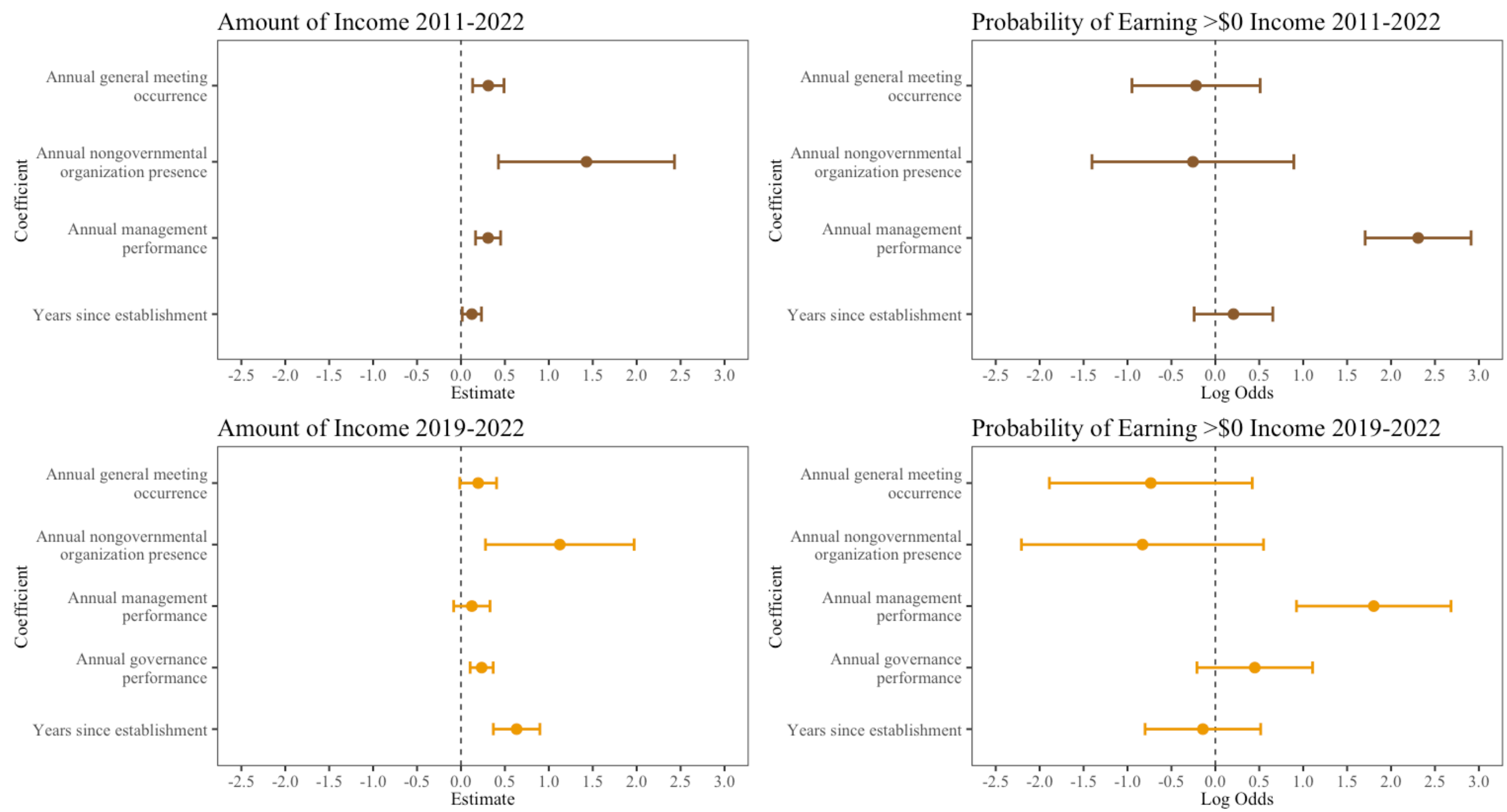

Figure 2.3: Standardized regression coefficient estimates with 95% confidence intervals (i.e., whiskers) for generalized linear mixed models fit to the (a) amount of income earned and (b) probability of earning >$0 income during 2011–2022, and (c) amount of income earned and (d) probability of earning >$0 income during 2019–2022 by communal conservancies in Namibia.

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APPENDIX A: CHAPTER 1 RESIDUAL DIAGNOSTIC PLOTS

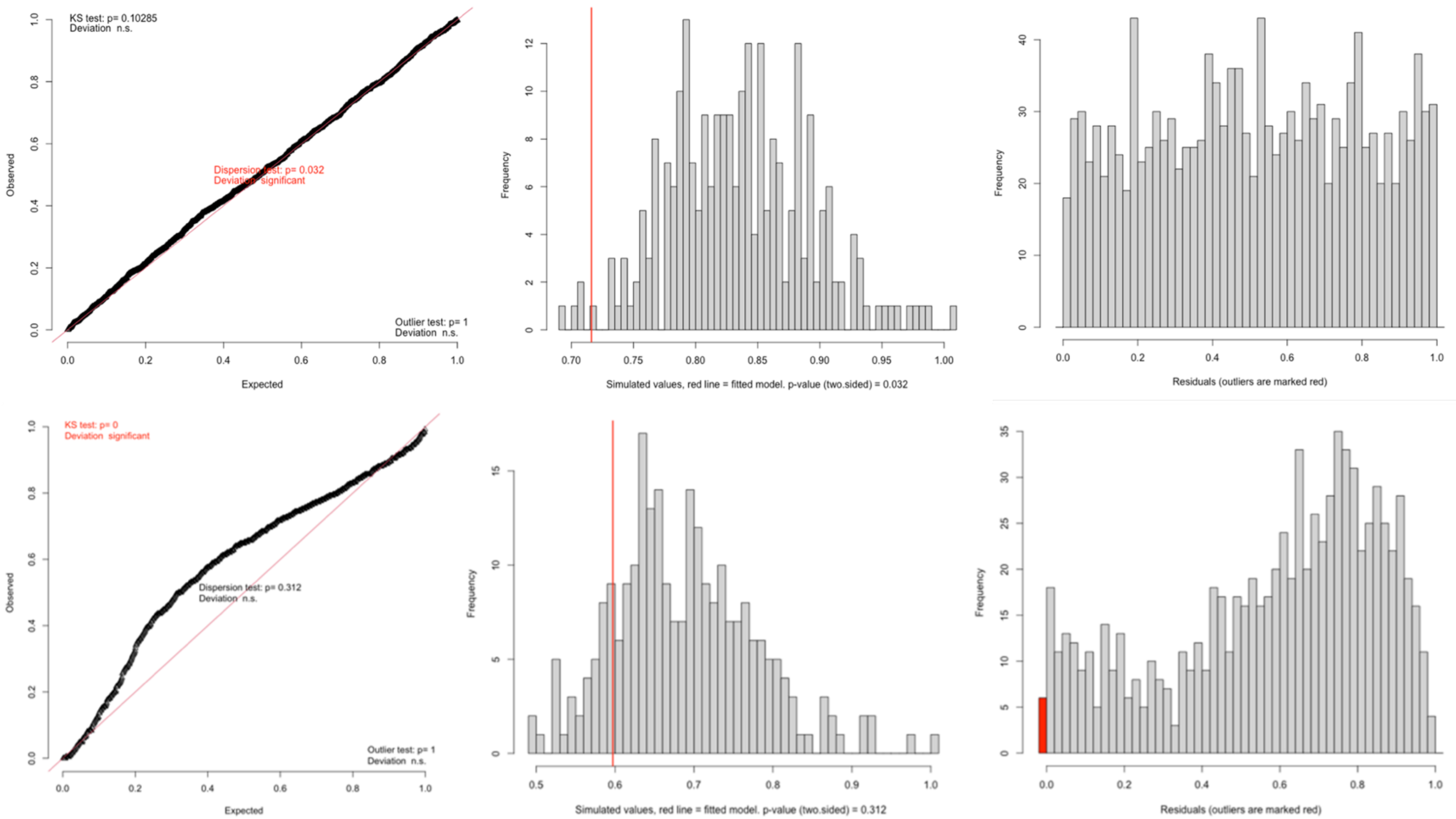

Figure A.1: Kolmogorov-Smirnov (left column), nonparametric dispersion (center column), and outlier (right column) test plots for generalized linear mixed models fit to the probability of earning >$0 hunting income (top row) and amount of hunting income (bottom row) earned by communal conservancies in Namibia, 1998–2022.

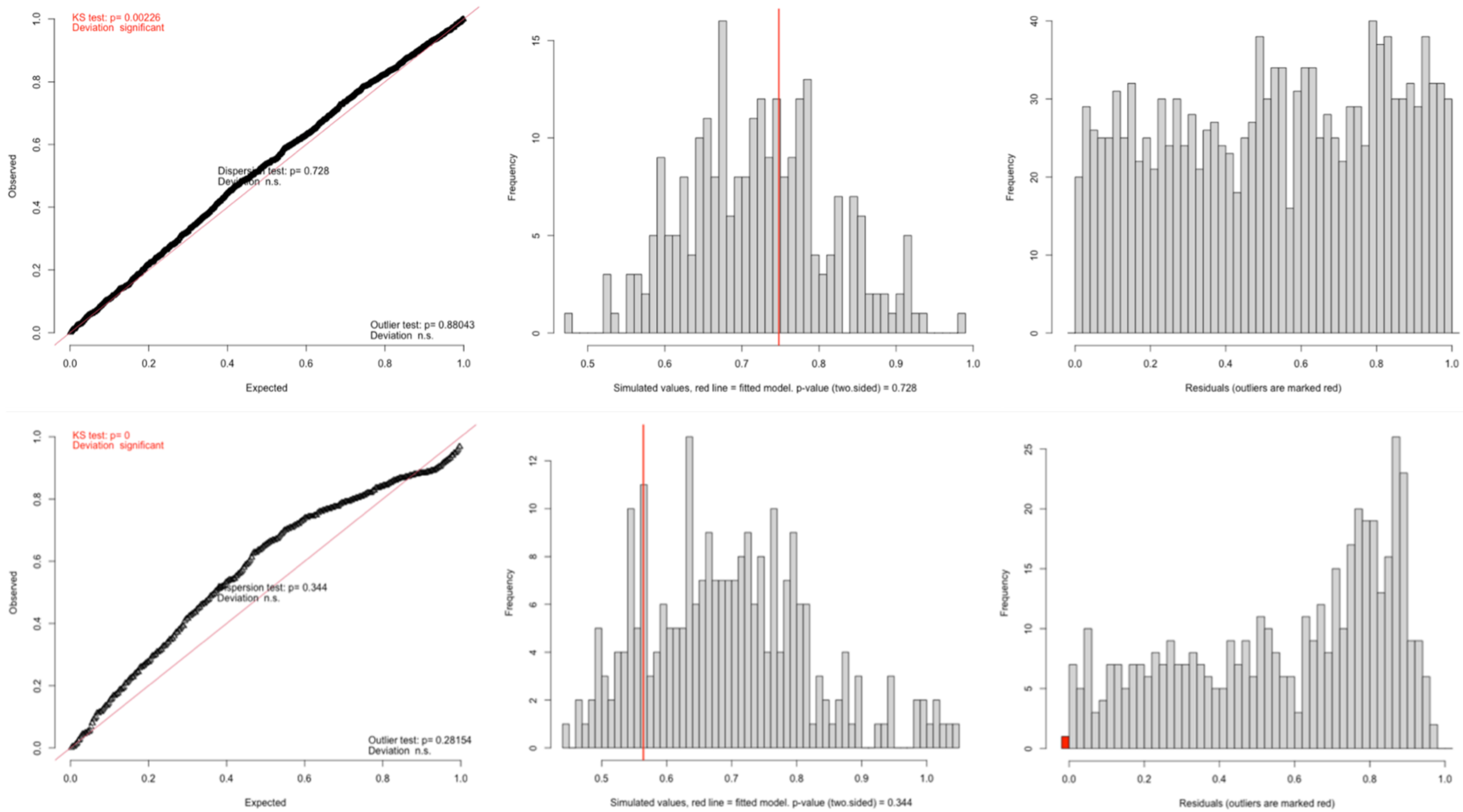

Figure A.2: Kolmogorov-Smirnov (left column), nonparametric dispersion (center column), and outlier (right column) test plots for generalized linear mixed models fit to the probability of earning >$0 photographic income (top row) and amount of photographic income (bottom row) earned by communal conservancies in Namibia, 1998–2022.

APPENDIX B: CHAPTER 1 REGRESSION COEFFICIENT TABLES

Table B.1: Regression coefficient log odds or estimates with 95% confidence intervals (CI) and *p*-values (< 0.05 bolded) for generalized linear mixed models fit to the probability of earning >$0 hunting income and amount of hunting income earned by communal conservancies in Namibia, 1998–2022.

	Probability of Earning >$0			**Amount of Hunting Income**		
Coefficient	*Log odds*	*CI*	*p-value*	*Estimate*	*CI*	*p-value*
Intercept	0.56	0.08 – 1.04	**0.022**	4.91	4.59 – 5.22	**<0.001**
Years since establishment	0.66	0.46 – 0.86	**<0.001**	-0.18	-0.26 – -0.10	**<0.001**
Area (km^2)	0.22	-0.31 – 0.75	0.417	0.37	0.02 – 0.72	**0.040**
Annual Big 5 species occurrence	0.88	0.60 – 1.16	**<0.001**	0.28	0.17 – 0.38	**<0.001**
Mean elevation (m)	-0.53	-1.03 – -0.03	**0.039**	-0.33	-0.63 – -0.02	**0.036**
Elevation SD (m)	0.37	-0.35 – 1.08	0.316	-0.89	-1.37 – -0.41	**<0.001**
Distance to nearest national park (km)	-0.40	-0.87 – 0.08	0.104	-0.43	-0.71 – -0.15	**0.003**
Distance to nearest major road (km)	-0.39	-1.04 – 0.27	0.243	-0.07	-0.49 – 0.35	0.736
Annual precipitation (mm)	0.35	-0.01 – 0.71	0.060	0.05	-0.11 – 0.20	0.539

Table B.2: Regression coefficient log odds or estimates with 95% confidence intervals (CI) and *p*-values (< 0.05 bolded) for generalized linear mixed models fit to the probability of earning >$0 photographic income and amount of photographic income earned by communal conservancies in Namibia, 1998–2022.

	Probability of Earning >$0			**Amount of Photographic Income**		
Coefficient	*Log odds*	*CI*	*p-value*	*Estimate*	*CI*	*p-value*
Intercept	-3.01	-4.04 – -1.97	**<0.001**	6.34	5.94 – 6.73	**<0.001**
Years since establishment	1.19	0.92 – 1.46	**<0.001**	0.38	0.27 – 0.48	**<0.001**
Area (km^2)	-0.09	-1.04 – 0.86	0.854	-0.08	-0.55 – 0.40	0.749
Annual Big 5 species occurrence	0.60	0.28 – 0.93	**<0.001**	0.12	-0.00 – 0.24	0.054
Mean elevation (m)	-2.52	-3.54 – -1.51	**<0.001**	-0.83	-1.24 – -0.43	**<0.001**
Elevation SD (m)	0.69	-0.54 – 1.92	0.273	0.63	-0.03 – 1.29	0.061
Distance to nearest national park (km)	-0.24	-1.11 – 0.64	0.594	0.13	-0.28 – 0.54	0.541
Distance to nearest major road (km)	0.29	-0.85 – 1.42	0.620	-0.44	-0.99 – 0.10	0.109
Annual precipitation (mm)	0.06	-0.37 – 0.50	0.781	0.25	0.03 – 0.48	**0.029**

APPENDIX C: MANAGEMENT PERFORMANCE INDICATORS

NATURAL RESOURCE MANAGEMENT – PERFORMANCE REVIEW QUESTIONNAIRE

Conservancy ……………………………...			**Year …………**
Commitment to Natural Resource Management			
1- Staffing	**The conservancy has committed staff to protecting its natural resources?**	0 – NONE 1 – WEAK 2 – MODERATE 3 – STRONG	- No staff - Volunteers only - Part-time NRM staff - Full-time NRM
2- Expenditure on NRM	**The conservancy is fully funding its NR maintenance activities and even investing to improve its resources?**	0 – NONE 1 – FAIR 2 – GOOD 3 – VERY GOOD 4 – EXCELLENT	- No expenditure - Paying for game guards using donor funds - Paying for game guards using own funds - Paying for all NRM costs using own funds - Using own funds for NR improvements such as wildlife introductions, game water, etc
3- Audit attendance	**All Community game guards (CGG) and committee are attending the event book audit?**	0 – NONE 1 – WEAK 2 – FAIR 3 – ACCEPTABLE 4 – GOOD 5 – VERY GOOD 6 – EXCELLENT	- No one was present - Not all event books are present and not all CGG's present - All event book are there but not all CGG's are present - All CGG's and event books are present - Same as previous but few committee members are present - Same as previous but Conservancy chairperson is present - Same as previous but all Committee members are present
Planning			
4- Management plan	**The conservancy has full management plan documentation?**	0 – NONE 1 – FAIR 2 – GOOD 3 – EXCELLENT	- No NR management plan - Draft NR management plan available - NR management plan endorsed by community - Management plan poster
5- Zonation	**The conservancy has fully implemented its zonation vision?**	0 – NONE 1 – WEAK 2 – FAIR 3 – GOOD 4 – EXCELLENT	- No zonation map -Draft zonation map - A community endorsed zonation - Evidence of implementation of the zonation - Full implementation of planned zonation
6- Leadership in NRM	**The conservancy is showing clear leadership in the management of its Natural Resources?**	0 – WEAK 1 – FAIR 2 – GOOD 3 – EXCELLENT	- Service providers leading all NRM activities - Conservancy leading one NRM activity - Conservancy leading at least two NRM activities - Conservancy leading all NRM activities
Monitoring			
7- Display of material	**The filing box and files in order?**	0 – WEAK 1 – FAIR 2 – EXCELLENT	- Some files are missing - All files are present - All files are neat and in good order
8- Event books modules	**The conservancy has a comprehensive local-level monitoring system in place?**	0 – NONE 1 – WEAK 2 – FAIR 3 – GOOD 4 – VERY GOOD 5 – EXCELLENT	- None - Partial (only yellow or blue level) event book in place - Full event book (yellow, blue and red) with less than 3 modules - Full event book with 4 to 6 modules - Full event book with almost all modules - All natural resources being monitored including red level and a fully completed year-end Audit report

Figure C.1: Annual natural resource audit report and performance review questionnaire template for communal conservancies in Namibia, 2020 (NACSO).

Figure C.1 (cont'd)

9- Event books quality	**The Game Guards are implementing their event book perfectly?**	0 – NONE 1 – WEAK 2 – FAIR 3 – EXCELLENT	- Event books are not used - Event books are not used by all CGG's - Event books are used by all CGG's but with a few mistakes - Event books perfectly completed with no mistakes
10- Compliance Reporting	**Conservancy is reporting all wildlife Removals and Introductions? (see the Yellow Book)**	0 – NONE 1 – PARTIALLY COMPLETED 2 – FULLY COMPLETED	- No compliance report - Partial (incomplete compliance report) - Full compliance reporting
11- Game count	**The conservancy is monitoring its key wildlife populations?**	0 – NONE 1 – FAIR 2 – GOOD 3 – VERY GOOD 4 – EXCELLENT	- None - Annual game count or monthly fixed route patrols - Annual game count and monthly fixed route patrols - Same as 2 but monthly fixed route patrols done for more than 8 months of the year - Same as 3 but breeding success also monitored
12- Reporting & adaptive management	**Game Guards are sharing information with all stakeholders and conservancy using information for decision-making?**	0 – NONE 1 – WEAK 2 – FAIR 3 – GOOD 4 – VERY GOOD 5 – EXCELLENT 6 – PERFECT	- Monthly reporting charts/ trend charts not compiled - Monthly reporting charts / trend charts done but not shared - Monthly charts/ trend charts shared with management - All Long-term reporting charts up to date and shared with management committee - Event book charts presented at AGM - Event book charts also presented at villages - Clear evidence of adaptive management decisions
Management			
13- Harvesting management	**The Conservancy is fully managing their harvest according to quotas and harvest methods?**	0 – NONE 1 – WEAK 2 – FAIR 3 – EXCELLENT	-Has no quota/ no management -Tickets system/game guard reports not implemented -Systems implemented but not registered or recorded -Systems implemented, registered and recorded in relevant books
14- Law enforcement	**The conservancy has almost completely eliminated illegal use of its Natural Resources?**	0 – NONE 1 – WEAK 2 – FAIR 3 – GOOD 4 – VERY GOOD 5 – EXCELLENT	- None - Only poaching monitoring undertaken - Casual patrolling & poaching monitoring - focused law enforcement patrolling - Evidence of follow-up and arrests - Poaching almost non-existent (zero incidents AND good patrolling effort)
15- Human-wildlife conflict	**The conservancy has solved most of its HWC problems?**	0 – NONE 1 – WEAK 2 – FAIR 3 – GOOD 4 – EXCELLENT	- No HWC action - Only recording problem animal incidents - Livestock (or crop) mitigation scheme in place - Livestock and crop mitigation schemes - HWC is almost non-existent
Benefits			
16- Sources of NR income	**The conservancy is utilizing a wide range of its natural resources?**	0 – no NR derived income 1 – income from 1 NR based activity 2 – income from 2 NR based activities 3 – income from 3 NR based activities 4 – income from 4 NR based activities 5 – income from 5 and more NR activities	
17- Benefits produced	**The conservancy is profiting from its natural resources?**	0 – NONE 1 – WEAK 2 – FAIR 3 – GOOD 4 – EXCELLENT	- No benefits from natural resources - Some resource-use - Some employment & income from natural resources - NR income meets NRM expenditure - NR income exceeds entire Conservancy expenditure

APPENDIX D: CHAPTER 2 RESIDUAL DIAGNOSTIC PLOTS

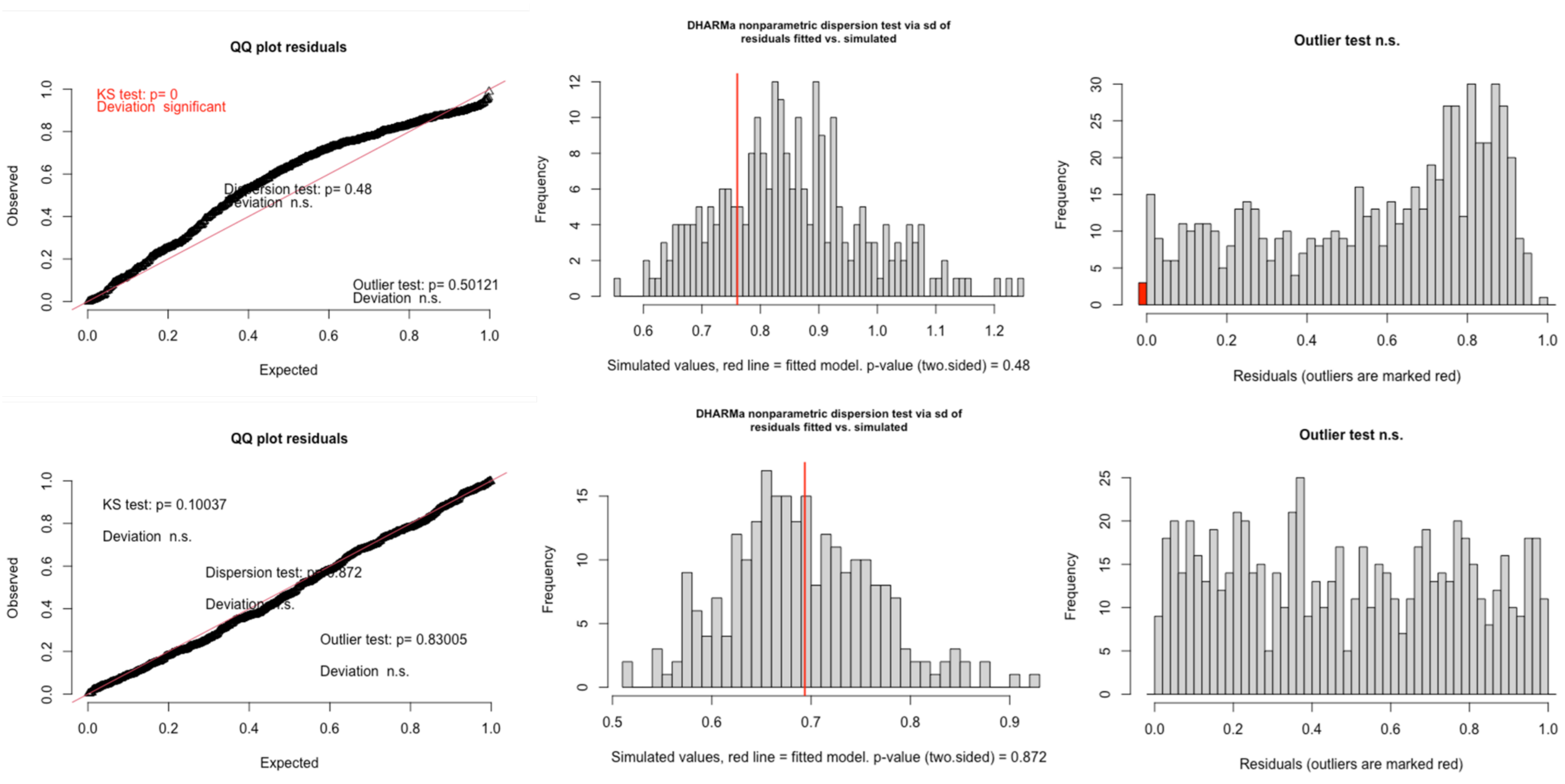

Figure D.1: Kolmogorov-Smirnov (left column), nonparametric dispersion (center column), and outlier (right column) test plots for generalized linear mixed models fit to the amount of income earned (top row) and probability of earning >$0 income (bottom row) by communal conservancies in Namibia, 2011–2022.

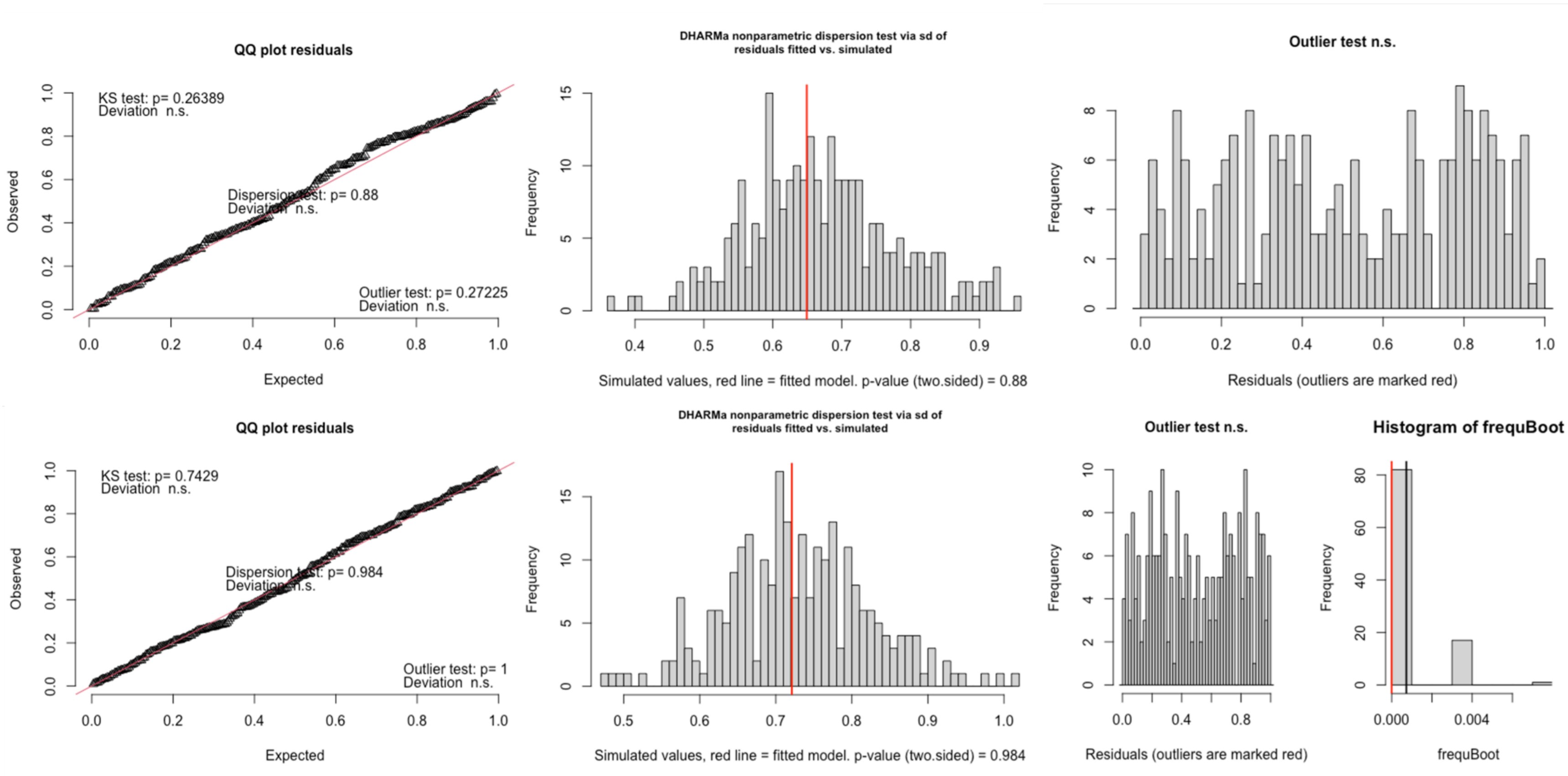

Figure D.2: Kolmogorov-Smirnov (left column), nonparametric dispersion (center column), and outlier (right column) test plots for generalized linear mixed models fit to the amount of income (top row) and probability of earning >$0 income (bottom row) by communal conservancies in Namibia, 2019–2022.

APPENDIX E: CHAPTER 2 REGRESSION COEFFICIENT TABLES

Table E.1: Regression coefficient log odds or estimates with 95% confidence intervals (CI) and *p*-values for generalized linear mixed models fit to the amount of income earned and probability of earning >$0 income by communal conservancies in Namibia, 2011–2022.

	Amount of Income			**Probability of Earning >$0**		
Coefficient	*Estimate*	*CI*	*p-value*	*Log odds*	*CI*	*p-value*
Intercept	-2.65	-3.57 – -1.73	**<0.001**	4.34	3.00 – 5.67	**<0.001**
Years since establishment	0.12	0.01 – 0.23	**0.026**	0.21	-0.24 – 0.66	0.367
Annual management performance	0.31	0.17 – 0.45	**<0.001**	2.37	1.75 – 2.99	**<0.001**
Annual nongovernmental organization presence	1.43	0.43 – 2.43	**0.005**	-0.26	-1.40 – 0.89	0.663
Annual general meeting occurrence	0.31	0.13 – 0.49	**0.001**	-0.22	-0.95 – 0.51	0.555

Table E.2: Regression coefficient log odds or estimates with 95% confidence intervals (CI) and *p*-values for generalized linear mixed models fit to the amount of income earned and probability of earning >$0 income by communal conservancies in Namibia, 2019–2022.

	Amount of Income			**Probability of Earning >$0**		
Coefficient	*Estimate*	*CI*	*p-value*	*Log odds*	*CI*	*p-value*
Intercept	-2.07	-2.85 – -1.28	**<0.001**	4.60	2.84 – 6.36	**<0.001**
Years since establishment	0.63	0.37 – 0.90	**<0.001**	-0.15	-0.86 – 0.55	0.672
Annual management performance	0.12	-0.08 – 0.33	0.241	1.80	0.92 – 2.68	**<0.001**
Annual governance performance	0.24	0.10 – 0.37	**<0.001**	0.45	-0.21 – 1.10	0.181
Annual nongovernmental organization presence	1.13	0.28 – 1.97	**0.009**	-0.83	-2.21 – 0.55	0.238
Annual general meeting occurrence	0.20	-0.01 – 0.40	0.067	-0.73	-1.89 – 0.42	0.213

APPENDIX F: DEPENDENCE TESTING FOR INTER-CHAPTER MODEL COVARIATE EFFECTS

I conducted analyses for Chapters 1 and 2 using logical groups of environmental and governance factors with different years of data (i.e., 1998–2022 and 2011–2022, respectively) and unique predictions for their effects on income sources (i.e., hunting or photographic tourism for Chapter 1 and total income for Chapter 2) earned by communal conservancies in Namibia, assuming independent model covariate effects across chapters. I tested for dependence between inter-chapter model covariate effects separately from analyses in Chapters 1 and 2. I first calculated Pearson's product-moment correlations r between income types (i.e., binary, nonzero) from each chapter and continuous covariates from the other chapter. I used generalized linear mixed models that included additional fixed-effect covariates from the other chapter if $|r| \geq 0.30$ with the corresponding income type.

Models fit to the probability of earning >$0 hunting income (Table F.1), amount of hunting income (Table F.2), and probability of earning >$0 photographic income (Table F.3) included annual management and governance performances as additional fixed-effect covariates, excluding 1998–2010 data. Models fit to the probability of earning >$0 total income since 2011 included annual Big 5 species occurrence (Table F.4) and to the amount of total income during 2011–2022 also included mean elevation (Table F.5) as additional fixed-effect covariates. All models included random intercepts by conservancy that incorporated implicit variation among conservancies across chapters. While some results differ from the original reported models in Chapters 1 and 2, overall conclusions remained the same.

Years since conservancy establishment positively affected the probability conservancies earned >$0 hunting income during 1998–2022 but had a negative effect since 2011 when annual management performance was included (Table F.1). Big 5 species occurrence and mean elevation were not correlated with the probability conservancies earned >$0 hunting income during 2011–2022, and mean elevation also was not correlated with the amount of hunting income during 2011–2022, when annual management and governance performances were included (Tables F.1–F.2). Distance to nearest national park positively affected the probability conservancies earned >$0 hunting income since 2011 when annual management performance was included (Table F.1). Big 5 species occurrence was not correlated with the probability conservancies earned >$0 photographic income during 2011–2022 when annual management and governance performances were included, while greater topographic diversity had a positive effect since 2019 (Table F.3). Annual management and governance performances positively affected the probability conservancies earned >$0 hunting and photographic income and the amount of hunting income during 2011–2022 with minimal changes to the significance or effect size of original covariates included in Chapter 1 (Tables F.1–F.3). Big 5 species occurrence increased the amount of total income since 2019 and lower mean elevation decreased the amount of total income during 2011–2022 with minimal changes to the significance or effect size of original covariates included in Chapter 2 (Table E.5).

Table F.1: Regression coefficient log odds or estimates with 95% confidence intervals (CI) and *p*-values (< 0.05 bolded) for generalized linear mixed models fit to the probability of earning >$0 hunting income by communal conservancies in Namibia, 2011–2022 and 2019–2022, including annual management (r = 0.65) and governance (r = 0.52) performances.

	Probability of Earning >$0 Hunting Income 2011–2022			**Probability of Earning >$0 Hunting Income 2019–2022**		
Coefficient	*Log odds*	*CI*	*p-value*	*Log odds*	*CI*	*p-value*
Intercept	1.87	1.37 – 2.36	**<0.001**	1.53	0.79 – 2.28	**<0.001**
Years since establishment	-0.56	-0.97 – -0.15	**0.007**	-0.48	-1.35 – 0.38	0.273
Area (km^2)	0.28	-0.20 – 0.77	0.255	0.12	-0.59 – 0.84	0.732
Annual Big 5 species occurrence	0.33	-0.13 – 0.80	0.157	0.46	-0.31 – 1.24	0.241
Mean elevation (m)	-0.17	-0.67 – 0.33	0.517	0.40	-0.35 – 1.14	0.295
Elevation SD (m)	-0.25	-0.88 – 0.38	0.432	-0.84	-1.83 – 0.14	0.093
Distance to nearest national park (km)	-0.60	-1.12 – -0.09	**0.020**	0.01	-0.72 – 0.73	0.985
Distance to nearest major road (km)	-0.56	-1.15 – 0.02	0.057	-0.87	-1.77 – 0.04	0.061
Annual precipitation (mm)	-0.02	-0.55 – 0.52	0.950	-0.79	-1.72 – 0.14	0.096
Annual management performance	1.91	1.41 – 2.41	**<0.001**	1.59	0.67 – 2.51	**0.001**
Annual governance performance	-	-	-	1.10	0.41 – 1.79	**0.002**

Table F.2: Regression coefficient log odds or estimates with 95% confidence intervals (CI) and *p*-values (< 0.05 bolded) for generalized linear mixed models fit to the amount of hunting income earned by communal conservancies in Namibia, 2011–2022 and 2019–2022, including annual management ($r = 0.44$ and $r = 0.40$, respectively) and governance ($r = 0.31$) performances.

	Amount of Hunting Income 2011–2022			**Amount of Hunting Income 2019–2022**		
Coefficient	*Estimate*	*CI*	*p-value*	*Estimate*	*CI*	*p-value*
Intercept	4.91	4.57 – 5.25	**<0.001**	4.82	4.60 – 5.04	**<0.001**
Years since establishment	-0.56	-0.69 – -0.43	**<0.001**	-0.23	-0.48 – 0.03	0.082
Area (km^2)	0.51	0.15 – 0.88	**0.006**	0.53	0.29 – 0.76	**<0.001**
Annual Big 5 species occurrence	0.17	0.02 – 0.32	**0.026**	0.55	0.29 – 0.82	**<0.001**
Mean elevation (m)	-0.32	-0.69 – 0.05	0.087	-0.18	-0.44 – 0.08	0.180
Elevation SD (m)	-0.89	-1.41 – -0.37	**0.001**	-0.72	-1.12 – -0.32	**<0.001**
Distance to nearest national park (km)	-0.48	-0.80 – -0.16	**0.003**	-0.15	-0.41 – 0.10	0.246
Distance to nearest major road (km)	-0.14	-0.63 – 0.34	0.570	0.04	-0.33 – 0.40	0.843
Annual precipitation (mm)	0.03	-0.13 – 0.19	0.739	0.13	-0.15 – 0.41	0.366
Annual management performance	0.33	0.19 – 0.48	**<0.001**	0.43	0.16 – 0.70	**0.002**
Annual governance performance	-	-	-	0.28	0.08 – 0.48	**0.006**

Table F.3: Regression coefficient log odds or estimates with 95% confidence intervals (CI) and *p*-values (< 0.05 bolded) for generalized linear mixed models fit to the probability of earning >$0 photographic income by communal conservancies in Namibia, 2011–2022 and 2019–2022, including annual management ($r = 0.47$) and governance ($r = 0.40$) performances.

	Probability of Earning >$0 Photographic Income 2011–2022			**Probability of Earning >$0 Photographic Income 2019–2022**		
Coefficient	*Log odds*	*CI*	*p-value*	*Log odds*	*CI*	*p-value*
Intercept	-2.62	-3.91 – -1.32	**<0.001**	-2.74	-4.33 – -1.15	**0.001**
Years since establishment	0.93	0.39 – 1.46	**0.001**	1.91	0.39 – 3.44	**0.014**
Area (km^2)	-0.43	-1.62 – 0.76	0.479	-0.59	-1.88 – 0.71	0.376
Annual Big 5 species occurrence	0.34	-0.22 – 0.90	0.234	0.34	-0.89 – 1.58	0.584
Mean elevation (m)	-2.83	-4.45 – -1.21	**0.001**	-2.01	-3.80 – -0.23	**0.027**
Elevation SD (m)	1.19	-0.39 – 2.76	0.141	2.23	0.17 – 4.29	**0.034**
Distance to nearest national park (km)	-0.34	-1.64 – 0.95	0.603	0.48	-0.94 – 1.91	0.504
Distance to nearest major road (km)	-0.04	-1.63 – 1.55	0.961	-0.78	-2.76 – 1.21	0.443
Annual precipitation (mm)	-0.29	-0.86 – 0.27	0.313	-0.78	-1.86 – 0.29	0.154
Annual management performance	1.12	0.41 – 1.83	**0.002**	2.02	0.52 – 3.53	**0.009**
Annual governance performance	-	-	-	1.38	0.33 – 2.43	**0.010**

Table F.4: Regression coefficient log odds or estimates with 95% confidence intervals (CI) and *p*-values (< 0.05 bolded) for generalized linear mixed models fit to the probability of earning >$0 total income earned by communal conservancies in Namibia, 2011–2022, including annual Big 5 species occurrence ($r = 0.34$).

	Probability of Earning >$0 Total Income 2011–2022		
Coefficient	*Log odds*	*CI*	*p-value*
Intercept	4.00	3.21 – 4.79	**<0.001**
Years since establishment	0.13	-0.33 – 0.59	0.576
Annual management performance	2.57	1.89 – 3.24	**<0.001**
Annual nongovernmental organization presence	-0.00	-0.47 – 0.47	0.996
Annual general meeting occurrence	-0.07	-0.38 – 0.23	0.642
Annual Big 5 species occurrence	-0.53	-1.16 – 0.10	0.102

Table F.5: Regression coefficient log odds or estimates with 95% confidence intervals (CI) and *p*-values (< 0.05 bolded) for generalized linear mixed models fit to the amount of total income earned by communal conservancies in Namibia, 2011–2022 and 2019–2022, including annual Big 5 species occurrence ($r = 0.40$ and $r = 0.37$, respectively) and mean elevation ($r = -0.45$).

	Amount of Total Income 2011–2022			**Amount of Total Income 2019–2022**		
Coefficient	*Estimate*	*CI*	*p-value*	*Estimate*	*CI*	*p-value*
Intercept	-1.12	-1.45 – -0.79	**<0.001**	-0.99	-1.27 – -0.71	**<0.001**
Years since establishment	0.13	0.02 – 0.24	**0.024**	0.52	0.26 – 0.77	**<0.001**
Annual management performance	0.31	0.16 – 0.45	**<0.001**	0.10	-0.10 – 0.31	0.328
Annual governance performance	-	-	-	0.21	0.08 – 0.34	**0.001**
Annual nongovernmental organization presence	0.44	0.12 – 0.75	**0.007**	0.32	0.01 – 0.63	**0.043**
Annual general meeting occurrence	0.12	0.05 – 0.19	**0.001**	0.10	0.01 – 0.18	**0.033**
Annual Big 5 species occurrence	0.08	-0.06 – 0.21	0.258	0.23	0.03 – 0.43	**0.025**
Mean elevation (m)	-0.84	-1.20 – -0.49	**<0.001**	-0.57	-0.88 – -0.25	**<0.001**