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Sciences, Togo
Hudson Laizer,
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of Science and Technology, Tanzania

*CORRESPONDENCE

Christopher M. Banotai
✉ cbanotai38@gmail.com

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Rooted in community: local perspectives on the cultural and conservation value of marula in rural South Africa

Christopher M. Banotai^{1,2*}, Craig R. Spencer² and
John L. Koprowski^{1,2,3}

¹Department of Zoology and Physiology, University of Wyoming, Laramie, WY, United States,

²Transfrontier Africa, Hoedspruit, South Africa, ³Haub School, University of Wyoming, Laramie, WY, United States

Non-timber forest products (NTFP) are vital to rural livelihoods, providing food, income, and cultural value. The marula tree (*Sclerocarya birrea* subsp. *caffra*) is a key NTFP species in Southern Africa, offering diverse uses and holding deep cultural significance. However, marula populations in South Africa's lowveld are declining due to elephant impact and poor seedling recruitment. This study examines local perceptions of marula's value, conservation, and management in the communities of Ga-Makushane and Namakgale. Older respondents had more positive perceptions of marula trees and their products and protected areas; most participants supported conservation and avoided harmful harvesting. Though, few interviewees actively planted seedlings or were aware of population declines. Medicinal use was widespread and support for elephant culling was low. Our findings support and locally contextualize prior suggestions that marula can be understood as a Cultural Keystone Species, while also indicating that complementary ethnolinguistic work is still needed before that interpretation can be evaluated more fully in this region. Findings underscore the importance of community-led initiatives, such as seedling programs, and advocate for management strategies that integrate local knowledge to sustain marula's ecological and cultural roles.

KEYWORDS

cultural keystone species (CKS), ethnobotany and local people, marula (*Sclerocarya birrea*), NTFP (non-timber forest product), plant conservation, semi-structured interview

Introduction

Non-timber forest products (NTFP) encompass a wide range of goods and resources of biological origin obtained from forests or other wooded lands without involving timber harvesting (Food and Agriculture Organization of the United Nations, 2020). These products, including items such as fruits, nuts, seeds, resins, medicines, as well as game products, play a crucial role in the livelihoods of many communities, providing sustenance, income, and cultural significance (Shackleton and Shackleton, 2004; Shackleton et al., 2011; Asamoah et al., 2024). An estimated 20% of the global population receives an essential resource for sustenance from forests (Cheng et al., 2019). NTFP often confer traditional knowledge and practices passed down from generation to generation (Asamoah et al., 2024; Berkes, 2009; Cunningham, 2001). The use of multiple

NTFP to meet a household's daily needs is common in rural South Africa, across a broad range of socioeconomic conditions and environments (Shackleton et al., 2025; Shackleton and Shackleton, 2004). Often, economically underprivileged households benefit the most from NTFP (Shackleton and Shackleton, 2004). Therefore, inadequate management and loss of access to NTFP can have dire consequences for the poorest in society (Mukhlis, 2019).

Understanding factors influencing NTFP use and knowledge transmission is critical for sustainably managing NTFP—both culturally and ecologically. Factors such as age may influence NTFP use and the transmission of cultural knowledge (Cocks et al., 2008). For example, older members of the community were marginally more likely to be reliant on NTFP across eight communities in Marrupa-Mecula Corridor, Niassa Special Reserve, Niassa Province of Mozambique (Lubega et al., 2022). If older generations pass away before transmitting cultural knowledge, or if younger generations are not receptive to continuing cultural traditions, this may lead to a downturn in NTFP use and loss of traditional knowledge (Araujo-Santos et al., 2025). Socioeconomic conditions can also shape the extent to which households rely on NTFPs for subsistence needs and income generation (Shackleton and Shackleton, 2004; Kamwi et al., 2020; Munanura et al., 2018). Surprisingly, Shackleton and Shackleton (2006) reported no differences in the proportion of households using NTFPs, nor in the total number of NTFPs used per household, across different wealth classes in South Africa. Through the use of natural resources, people often develop close and enduring relationships with the species around them—in some cases, these relationships become so strong that particular species help shape cultural identity and social practice (Garibaldi and Turner, 2004; Mattalia et al., 2025). These species, “species that shape in a major way the cultural identity of a people” are known as Cultural Keystone Species (CKS; Garibaldi and Turner, 2004). Natural resource use and knowledge transmission are integrally entwined with the CKS Concept (Garibaldi and Turner, 2004). Although NTFP use in Africa is common, the CKS concept is under-represented outside the Western Hemisphere as approximately half of all reported CKS are located in North America (Mattalia et al., 2025). African examples of cultural keystone species remain comparatively understudied, not because culturally important species are lacking, but because the framework has been developed and applied unevenly across regions, with most case studies and formal evaluations concentrated in North America and relatively few reproducible assessments conducted in Africa (Mattalia et al., 2025). Historically, marula provided food, beverages, medicine, wood, and shade, while also holding ceremonial, spiritual, and social significance (Shackleton et al., 2015; Mariod and Abdelwahab, 2012; Wynberg et al., 2002). Marula's cultural roles were embedded in rites of passage, ancestor communication, and community celebration, positioning it as both a cultural pillar and ecological keystone (Shackleton et al., 2015; Garibaldi and Turner, 2004). Marula conservation discourse sits at the intersection of NTFP use and culture, making it a strong case for fine-scale evaluation of how well local interview data support that keystone interpretation (Garibaldi and Turner, 2004; Blair et al., 2021; Cook et al., 2025; Wynberg et al., 2002; Murry, 2017). While marula appears to remain abundant in human communities, it is declining within protected areas of the Greater Kruger Ecosystem (Helm and Witkowski, 2013; Jacobs and Biggs, 2002; Cook et al., 2017).

The issue of marula conservation intersects with the management and conservation of another iconic and ecological keystone species, the African bush elephant (*Loxodonta africana*) (Wilson et al., 2021; Dzinotizei et al., 2018). In protected areas within the Greater Kruger

Ecosystem (GKE) this decline is characterized by two primary facets: mortality of adult trees, often driven directly and indirectly by elephant impact (Helm and Witkowski, 2013), and a lack of recruitment of new trees into the populations, which is influenced by a suite of factors beyond elephant impact such as land use, fire, and herbivory by other species (Helm and Witkowski, 2013; Jacobs and Biggs, 2002; Helm et al., 2011). Despite this ecological complexity, the culling of elephants (and/or the increased hunting of elephants) are often presented as consummate solutions to marula's tribulations by segments of the public and some managers (Hendry, 2021; Henley and Cook, 2019; Cook et al., 2025). Because elephant impacts are frequently invoked in explanations and management debates surrounding marula decline, community perceptions of elephants and their management are relevant to understanding how local people interpret broader marula conservation challenges and potential interventions. In regions with high levels of human-elephant conflict such as crop raiding, culling elephants often receives more support as a potential strategy (Ngorima et al., 2020). In communities without this pressure, positive sentiment towards elephant culling is less common (Kerley and Shrader, 2007). Often, conservation policy-making misses the opportunity to incorporate perspectives of local communities in the development process—leading to poor relationships between local communities and protected areas (Abukari and Mwalyosi, 2020; Renn, 2001; Rampheri and Dube, 2021). It is in protected areas' best interests to maintain positive relationships with their local communities.

Our study aims to use local semi-structured interviews paired with cumulative logit ordinal regression and Bayesian statistical analysis to evaluate alignment of marula's prior treatment as a CKS with the diagnostic criteria laid out by Garibaldi and Turner, further elucidating the cultural, economic, and spiritual relationships that rural South Africans in Limpopo Province have with marula trees and their products. We conducted surveys investigating the following questions: (1) how perspectives on marula's cultural, economic, and conservation values vary across demographic factors, especially age, (2) how community attitudes relating to marula conservation interact with perceptions of protected areas and elephant management, and (3) to what extent does marula align with the diagnostic criteria defining the cultural keystone species concept laid out by Garibaldi and Turner (2004) and prior classification as a CKS by works such as Shackleton et al. (2015)? We hypothesized (a) that traditional knowledge and tight human-marula relationships would be more common among older individuals as communities develop, and (b) culling elephants would be an unpopular management strategy. The results of our surveys could inform management decisions concerning marula's at-risk populations within protected areas in the Greater Kruger Region and bring the voices of regional stakeholders to the decision-making table, facilitating relationships between local communities and protected areas.

Study area

We selected two communities in the Greater Kruger region of South Africa based upon the region's overlap with marula distribution, the region's historical cultural relationship with marula trees and their products, as well as the proximity to the marula population declines in local protected areas. Namakgale (23.9375° S, 31.0306° E) is a township approximately 12 km outside Phalaborwa, the nearest city, in the Mopani District of Limpopo and has an estimated population of 36,365 according to the most recent census available for these exact locales, 2011 (Stats SA). Namakgale is the site of the annual Marula Festival,

which takes place in February and March. Ga-Makhushane is located in Ba-Phalaborwa local municipality, within the province of Limpopo. (23.9635° S, 31.0446° E) and has an estimated population of 12,499 (Stats SA). As of 2022, the Ba-Phalaborwa Local Municipality population was 188,603 people, up from 150,637 in 2011 (Stats SA, 2025).

The surrounding landscape is characterized by a mosaic of settlement, communal land use, and proximity to protected areas within the broader Greater Kruger conservation region (Nyathi et al., 2025). Livelihoods in this part of Limpopo commonly include a mix of wage labor, informal economic activity, social support systems, and continued reliance on natural resources for household provisioning (Piet and Mtapuri, 2014). Within this context, marula is a familiar and culturally visible species in the regional landscape, and its fruits and derived products remain socially and economically recognizable resources (Shackleton et al., 2002). This broader social-ecological setting made the study area appropriate for examining how local communities perceive marula use, value, and conservation in relation to nearby protected-area concerns (Nyathi et al., 2025; Fabricius et al., 2004).

Methods

Our semi-structured surveys were a mix of 14 Likert Scale questions and statements (Likert, 1932) and nine yes or no questions. We employed a Likert scale including strongly disagree (1), disagree (2), neutral (3), agree (4), and strongly agree (5)—a standard approach to evaluating sentiment in structured surveys. Surveys were tested in the community of Maseke, which was not part of the study area. We conducted 30 surveys in the township of Namakgale and 30 in the village of Ga-Makushane. We interpret the results as locally informative and hypothesis-generating rather than fully representative of all communities in Limpopo or the Greater Kruger region. All surveys were voluntary and no incentives were offered for participation. Before performing the surveys, we obtained approval from tribal officials of each community.

Sampling design

We employed a systematic, household-based sampling approach. We selected sampling locations by traversing main residential areas in the communities, then selecting a street, and approaching every other house on the right side of the street for surveying (see Sinthumule and Mzamani, 2019). We used this systematic spacing approach to reduce *ad hoc* household selection and to improve spatial spread of sampled households within each community, although it does not eliminate all sources of sampling bias. If someone was home (visible or outdoors), we approached the house, and our translator delivered the traditional greeting. If the occupants were not home, we moved on, skipping the adjacent house, moving on to the next eligible house. If the potential interviewee expressed interest in participating in the survey, the consent form was read and reviewed with the aid of the translator. Survey materials were presented and recorded in paper form. Our translator presented each question to the interviewees and was present for further review if requested. Although translator-mediated interviews may introduce some interpretive variation, use of a single translator and prior review of survey materials helped improve consistency across interviews. Through the translator, translation was available between several languages including Xitsonga, isiXhosa, Sepede, and English. Interviewees consisted of one adult (≥ 21 years old) individual from each household, self-identifying as

the head of household or delegated by the head of household, was surveyed. While this approach does not ensure full demographic representativeness, it allowed broad coverage across communities and within logistical constraints and reduced reliance on convenience-based sampling. Personal information of participants was anonymized and confidential. All survey materials were reviewed and approved by the Institutional Review Board of University of Wyoming (Protocol #20230505JK03563). We focused on two areas with our questionnaires, the first was attitudes of residents (Table 1) then, a more detailed assessment of use of marula and elephant management (Table 2).

Analysis

We used a Wilcoxon Test to compare age across communities and Fisher's Exact Tests to evaluate whether respondent sex, education, employment status, and overall response distributions differed between communities to assess if joint analysis was warranted. Only the distribution of interviewees' ages differed between communities, with Namakgale (mean age = 48.3) being slightly older than Ga-Makushane (mean age = 43.8) ($p = 0.003$). Because the two communities were situated within the same broader social-ecological setting and differed among our covariates only in respondent age, we analyzed them jointly to evaluate overall patterns in local perceptions while retaining both community and age as predictors in all models.

Because the questionnaire responses were ordinal, we modeled each question separately using cumulative logit ordinal regression, which preserves the ordered nature of Likert data and avoids the information loss associated with collapsing categories into binary outcomes (Agresti, 2010; Liddell and Kruschke, 2018). We fit ordinal models using the ordinal and brms packages (Christensen, 2025; Bürkner, 2017, 2018). For each survey item, we first fit a frequentist cumulative logit model using `clm()` in ordinal, restricting predictors to those that varied within the item-specific subset. When `clm()` failed or produced unstable standard errors, we fit a Bayesian cumulative logit model using brms as a fallback to address sparse response structure and separation. In Bayesian fallback models, we used weakly informative priors [Normal (0, 1.5) for slope coefficients and Student-t (3, 0, 2.5) for thresholds], two parallel Markov chains, and 2,000 post-warmup iterations per chain. We assessed Bayesian model convergence using trace inspection and $\hat{R} < 1.01$, and we used posterior predictive checks via `pp_check()`. We modeled each question independently because our objective was to evaluate item-specific relationships between demographic predictors and particular perceptions or behaviors rather than estimate a single composite attitude construct across heterogeneous survey domains. Effects are reported as odds ratios (ORs); uncertainty is summarized using Wald 95% confidence intervals for `clm()` models and 95% credible intervals for Bayesian fallback models. For each question i and respondent j , the model took the form:

$$\text{score}_{ij} \sim \text{CumulativeLogit}(\alpha_k, \beta_1 \text{age}_j + \beta_2 \text{sex}_j + \beta_3 \text{education}_j + \beta_4 \text{employment}_j + \beta_5 \text{community}_j)$$

Where α_k represents ordered category thresholds and β coefficients represent the change in log-odds of selecting a higher category per unit change in the covariate. This question-specific approach aligned with our study objectives by allowing us to examine how demographic factors related separately to perceptions of marula value, conservation, protected areas, and elephant management. We treated

TABLE 1 Responses to Likert-scale items concerning marula value and protection, protected areas, and elephants among pooled respondents from Ga-Makushane and Namakgale, Limpopo, South Africa ($n = 60$; 30 respondents per community).

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
A. Perceived value and importance of marula					
Marula trees have a positive effect on my community.	0 (0.0%)	0 (0.0%)	1 (1.7%)	9 (15.0%)	50 (83.3%)
Marula trees have a positive economic impact on my community.	2 (3.3%)	2 (3.3%)	2 (3.3%)	10 (16.7%)	44 (73.3%)
Marula products are an important part of my life.	0 (0.0%)	3 (5.0%)	1 (1.7%)	7 (11.7%)	49 (81.7%)
Marula trees and their products are culturally important to me.	0 (0.0%)	1 (1.7%)	0 (0.0%)	6 (10.0%)	53 (88.3%)
B. Marula protection attitudes and practices					
I do not cut the branches of marula trees when harvesting fruits.	1 (1.7%)	0 (0.0%)	0 (0.0%)	2 (3.3%)	57 (95.0%)
Marula trees should be protected wherever they are found.	0 (0.0%)	3 (5.0%)	0 (0.0%)	7 (11.7%)	50 (83.3%)
I work to plant and protect marula seeds and seedlings.	18 (30.0%)	5 (8.3%)	0 (0.0%)	13 (21.7%)	24 (40.0%)
Fruit trees such as marula are traditionally protected because they are a source of food.	1 (1.7%)	1 (1.7%)	1 (1.7%)	10 (16.7%)	47 (78.3%)
Traditional laws or taboos in this community prohibit cutting marula trees.	3 (5.0%)	0 (0.0%)	4 (6.7%)	3 (5.0%)	50 (83.3%)
C. Protected areas and conservation					
I support the conservation of marula trees in protected areas outside the town or village.	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (16.7%)	50 (83.3%)
I have a positive perspective on protected areas.	0 (0.0%)	3 (5.0%)	1 (1.7%)	7 (11.7%)	49 (81.7%)
Protected areas and wildlife conservation have a positive impact on my life.	2 (3.3%)	5 (8.3%)	2 (3.3%)	4 (6.7%)	47 (78.3%)
D. Elephant perceptions and management					
I have a positive perception of elephants.	8 (13.3%)	8 (13.3%)	7 (11.7%)	8 (13.3%)	29 (48.3%)
Elephants should be managed via culling to protect marula trees.	38 (63.3%)	11 (18.3%)	3 (5.0%)	3 (5.0%)	5 (8.3%)

Values are presented as n (%), based on a five-point Likert scale ranging from strongly disagree to strongly agree. Overall, responses indicated strong positive perceptions of marula's community, economic, and cultural importance, broad support for marula protection in both community and protected-area contexts, generally positive views of protected areas, and comparatively weaker support for elephant culling as a management strategy.

age as a continuous predictor allowing for detection of directional trends by regression analysis. All other predictors were coded as categorical factors with reference levels corresponding to male, no formal education, unemployed, and Ga-Makushane.

This combined cumulative logit regression and Bayesian approach of modelling each question as an ordered response allowed us to analytically link interviewees' perceptions of marula value, conservation, and management preferences with demographic predictors within a unified framework.

For `clm()` models, uncertainty was summarized using Wald 95% confidence intervals, whereas for Bayesian fallback models fit in `brms`, uncertainty was summarized using 95% credible intervals. An $OR > 1$ indicates that increasing the predictor (e.g., older age or community membership, depending on coding) was associated

with higher odds of selecting a stronger response category, whereas $OR < 1$ indicates the opposite. All analyses were conducted in R v4.3.3 using RStudio 2023.06.2 + 561 ("Mountain Hydrangea"; R Core Team, 2024).

Results

Our surveys administered in the communities of Ga-Makushane and Namakgale demonstrated strong support for marula trees and elephants as indicated by Likert scores for each question. Thirty interviewees were surveyed in each community, for a total of 60 interviewees.

TABLE 2 Yes/no responses concerning marula use, conservation awareness, medicinal use, and elephant-related experience among pooled respondents from Ga-Makushane and Namakgale, Limpopo, South Africa ($n = 60$; 30 respondents per community).

Question	Yes	No
A. Marula food and product use		
I eat marula fruit.	57 (95.0%)	3 (5.0%)
I eat marula kernels/seeds.	56 (93.3%)	4 (6.7%)
I make marula beer or juice.	50 (83.3%)	10 (16.7%)
I purchase marula beer or juice.	21 (35.0%)	39 (65.0%)
I carve marula wood to make home goods or sculptures.	11 (18.3%)	49 (81.7%)
B. Marula conservation awareness and local valuation		
I am aware of declining marula populations in protected areas.	32 (53.3%)	28 (46.7%)
Female marula trees are more valued in my community than male trees.	53 (88.3%)	7 (11.7%)
C. Medicinal use of marula		
I use marula medicinally.	26 (43.3%)	34 (56.7%)
D. Elephant-related experience		
I have seen an elephant in person.	57 (95.0%)	3 (5.0%)

Values are presented as n (%). Incomplete follow-up prompt rows (e.g., ‘How often?’) are not shown. Responses indicate widespread use of marula fruit, kernels, and beverages, more limited wood-carving and medicinal use, moderate awareness of marula decline in protected areas, and near-universal direct experience with elephants.

Socio-economic profile of interviewees

Fewer than 10 potential interviewees declined participation across both communities. Respondents in both communities were more often female than male, had relatively low formal education levels, and experienced high unemployment. In Ga-Makushane, 20 interviewees (66.7%) identified as female and 10 (33.3%) as male, whereas in Namakgale, 17 interviewees (56.7%) identified as female and 13 (43.3%) as male. Respondents in Namakgale were slightly older overall than those in Ga-Makushane: the maximum age in both communities was 88 y, but mean and median age were 48.2 y and 45 y in Namakgale compared with 43.8 y and 40.5 y in Ga-Makushane. Levels of formal education were similarly low in both communities. In Ga-Makushane, 19 interviewees (63.3%) had less than a high school education, 5 (16.7%) had completed high school, and 6 (20%) had at least some college education; in Namakgale, 18 interviewees (60%) had not completed high school, 7 had completed high school, and 5 (16.7%) had at least some college education. Unemployment was also high in both communities, suggesting that marula and other useful natural resources may be perceived in a context where livelihood support and household provisioning are especially important. In Ga-Makushane, 22 interviewees (73.3%) were unemployed, 5 (16.7%) were employed, and 3 individuals (10%) were retired. In Namakgale, 19 interviewees (63.3%) were unemployed, 8 (26.7%) were formally employed, and 3 (10%) were retired. Three individuals (10%) in Namakgale who identified as unemployed also identified themselves as traditional healers.

Impacts of marula trees

Across both communities, perceptions of marula were strongly positive, with 59 of 60 (98.3%) respondents agreeing or strongly agreeing that marula trees have a positive effect on their community, 54 of 60 (90.0%) that marula has an economic impact on the community, 56 of 60 (93.3%) that marula products are an important part of their lives, and 59 of 60 (98.3%) that marula trees and their products are

culturally important. Each additional year of age was associated with an approximately 11% increase in the odds of expressing stronger agreement that marula trees have a positive impact on the community (Q1 OR = 1.11 [1.03–1.21], Figure 1) and an approximately 10% increase in the odds of expressing stronger agreement that marula trees are an important part of one's life (Q13 OR = 1.10 [1.03–1.20], Figure 2), indicating that these positive perceptions became progressively stronger among older respondents.

Protecting marula trees

Across both communities, interviewees reported strong support for marula protection and generally low endorsement of harmful harvesting practices: 59 of 60 respondents (98.3%) agreed or strongly agreed that they do not cut branches when harvesting fruit, 57 of 60 (95.0%) agreed or strongly agreed that marula trees should be protected wherever they are found, 57 of 60 (95.0%) agreed or strongly agreed that fruit trees such as marula are traditionally protected because they are a source of food, 37 of 60 (61.7%) agreed or strongly agreed that they work to plant and protect marula seeds and seedlings, 53 of 60 (88.3%) agreed or strongly agreed that traditional laws or taboos in their community prohibit cutting marula trees, and all 60 respondents (100.0%) agreed or strongly agreed that marula trees in protected areas outside the town or village should be conserved. By contrast, only 32 of 60 interviewees (53.3%) reported awareness of declining marula populations in protected areas, indicating that scientific recognition of marula decline in the Greater Kruger Ecosystem has only been partially reflected in community awareness. No measured covariates meaningfully influenced whether an individual cut the branches of marula when harvesting the fruit; whether individuals believed marula trees must be protected wherever they are found; or whether individuals were aware of declining marula populations in protected areas. On average, Namakgale respondents (coded 2) had slightly lower odds of planting marula seedlings (OR = 0.34 [0.13–0.91]). Practically, this means that respondents from Namakgale had about 66% lower odds of reporting that they plant marula seedlings

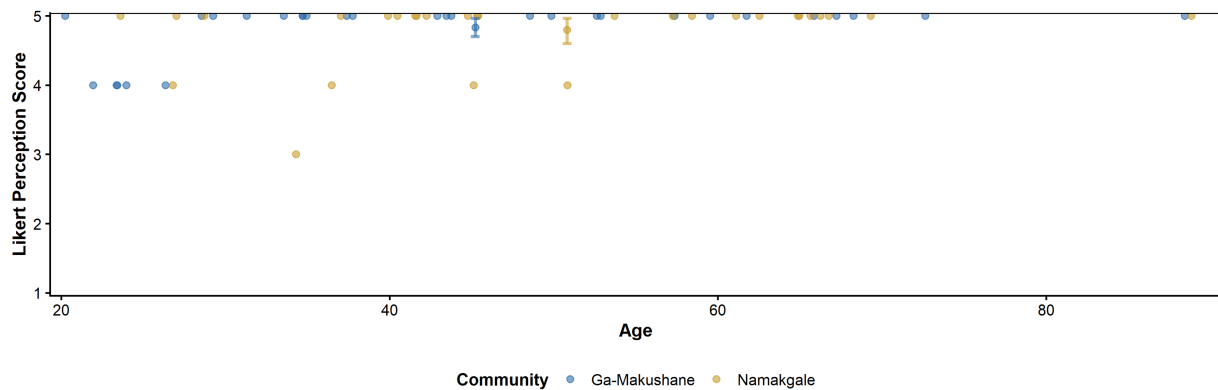


FIGURE 1

Relationship between respondent age and Likert perception score for Marula's positive effect on the community among 60 interviewees from two rural communities in Limpopo Province, South Africa ($n = 30$ each community). Scores range from 1 to 5, with higher scores indicating stronger perceived positive community impact. Points show individual responses, colored by community.

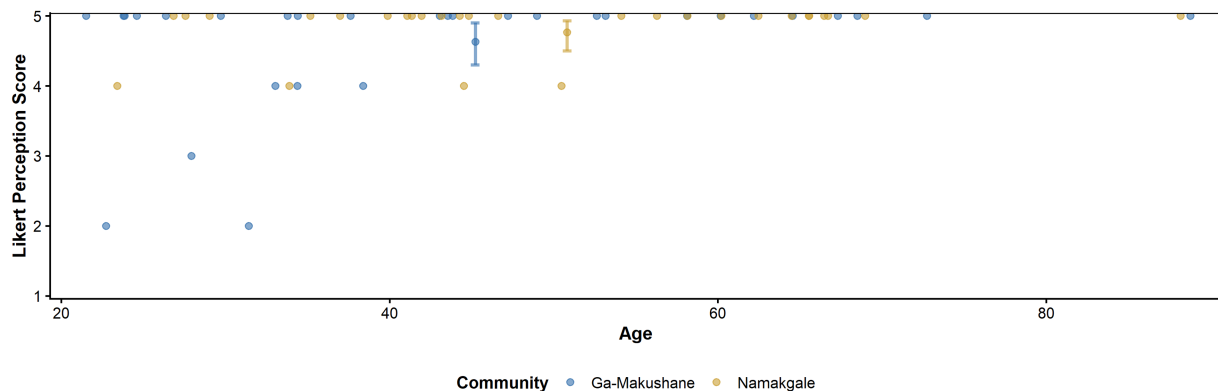


FIGURE 2

Relationship between respondent age and Likert perception score for the statement that marula products are an important part of respondents' lives among 60 interviewees from two rural communities in Limpopo Province, South Africa ($n = 30$ each community). Scores range from 1 to 5, with higher scores indicating stronger agreement. Points show individual responses, colored by community.

than respondents from Ga-Makushane, highlighting a need for intervention.

Medicinal use

Approximately half of interviewees ($n = 26$, 43.33%) reported using marula medicinally across both communities. In these communities, marula was reported as a treatment for a wide range of ailments, most commonly gastrointestinal complaints ($n = 16$), including diarrhea, stomach aches, and ulcers. Other reported uses fell into reproductive and maternal care (4), including assisting struggling newborns, menstrual pains, and post-pregnancy care; infectious and parasitic conditions ($n = 4$), including flu, sexually transmitted infections, and parasites; and pain- or injury-related complaints ($n = 7$), including tooth aches, wounds, headaches, ear pain, kidney pain, and back pain. Marula was also mentioned for blood pressure ($n = 1$) and as a panacea ($n = 1$). The plant parts used most often include bark ($n = 23$), roots ($n = 6$), fruit ($n = 2$) and leaves ($n = 1$). Bark was reportedly cut, ground, and boiled before the mixture is ingested, or, dried, ground, and ingested. Roots were reportedly soaked overnight, or ground and boiled before the mixture was ingested. Fruit is dried before being ingested. Leaves are mashed, before being boiled in water and the mixture ingested. No

measured covariates meaningfully influenced whether individuals were likely to use marula medicinally ($p > 0.05$).

Protected areas and marula management

In practical terms, each additional year of age was associated with an approximately 6% increase in the odds of reporting a more positive view of local protected areas (Q16 OR = 1.06 [1.00–1.14], Figure 3), suggesting that older respondents may hold more favorable perceptions because of longer-term familiarity with protected areas, which in turn may shape how different age groups engage with conservation issues. Culling elephants was an unpopular management strategy (strongly disagree: 63.3%, disagree: 18.3%, neutral: 5%, agree: 5%, strongly agree: 8.3%) to protect marula trees, though there were no trends among measured covariates regarding this (Figure 4).

Discussion

Protected areas should benefit from the incorporation of local community perspectives into management decision-making to achieve sustainable solutions and foster positive relationships with their local communities (Oldekop et al., 2015; Stephanson and Mascia, 2014;

Bennett and Dearden, 2014; Berkes, 2007; West and Brockington, 2006; Vodouhê et al., 2010; Naidoo et al., 2019; De Vos et al., 2017; Rampheri and Dube, 2021). Marula populations are a valuable case study to investigate local perceptions of a traditional resource and how this resource should be best managed in protected areas. Our study suggests that age influences perceptions of marula value and use among rural South Africans, likely reflecting age-related differences in traditional ecological knowledge, lived experience with marula-based practices, and exposure to intergenerational knowledge transmission (Lubega et al., 2022; Constant and Tshisikhawe, 2018; Mothupi and Shackleton, 2025). The diverse socio-economic profile of the interviewees provides an important context for understanding the perspectives shared in this study. The communities of Ga-Makushane and Namakgale are characterized by a diverse range of ages, educational backgrounds, and employment statuses. Notably, most interviewees had not completed high school, and unemployment was prevalent in both communities. Because interviews were conducted at respondents' homes during the standard work week (Monday–Friday) and typical daytime hours (09:00–17:00), the composition of the study sample was likely shaped in part by who was available at home during those times. However, this group provides valuable insight as research in other contexts has shown that communities with limited economic opportunities often place greater value on accessible natural resources for subsistence and income generation (Shackleton and Shackleton, 2004; Assembe-Mvondo et al., 2015).

There are several primary limitations of this study which warrant consideration. First, our modest sample size ($n = 60$) constrained statistical power and the ability to generalize our findings beyond the surveyed communities. Second, while our results suggest that marula aligns with multiple of the CKS diagnostic criteria laid out by Garibaldi and Turner (2004) which are outlined in this study, the authors were unable to conduct the ethnolinguistic work necessary to evaluate marula's significance in regional languages, which is highly warranted. While acknowledging these limitations, we suggest that this work be utilized as a launching point for further evaluation of how strongly marula satisfies CKS criteria in this regional context as well as an accompaniment for the ethnolinguistic work necessary to fully evaluate the criteria laid out in Garibaldi and Turner (2004).

Marula and the cultural keystone species framework. In local communities, marula products are still used for a wide range of purposes.

Consumption of marula fruit and nuts as well as brewing marula beer are common. Our analyses showed that consumption of marula fruits and kernels was widespread across socio-economic profiles, a pattern that aligns with reports from other parts of southern Africa where marula is widely used for food and other household needs across rural communities (Gouwakinnou et al., 2011; Mguni et al., 2023; Sinthumule and Mashau, 2019). Carving marula wood to produce home goods was uncommon, though several interviewees mentioned producing traditional drums from marula wood. The medicinal use of marula was slightly more common in Ga-Makushane than Namakgale, however, was ubiquitous across socio-economic profiles. This study adds local interview-based evidence to a body of work that has already highlighted marula's outsized cultural and ecological importance.

First introduced by Nabhan and Carr (1994) and later thoroughly defined by Garibaldi and Turner (2004) cultural keystone species can be defined as culturally pertinent species that significantly shape the cultural identity of a people, as evidenced by the fundamental roles these species have in diet, materials, medicine, and/or spiritual practices. Specifically, Garibaldi and Turner (2004) suggested that a cultural keystone species be defined by the following criteria: (1) intensity, type, and multiplicity of use; (2) naming and terminology in a language, including the use as seasonal or phenological indicators; (3) role in narratives, ceremonies, or symbolism; (4) persistence and memory of use in relationship to cultural change; (5) level of unique position in culture, e.g., difficult to replace with other available native species; and (6) extent to which it provides opportunities for resource acquisition from beyond the territory.

Consistent with earlier treatments of marula as a biocultural keystone in the NTFP literature (e.g., Shackleton et al., 2015), our interview data show multiplicity of use, continued ceremonial relevance, perceived irreplaceability, and links to local livelihood support, also aligning with the diagnostic criteria laid out by Garibaldi and Turner (2004). We show that marula has a multiplicity of uses on a consistent basis year-to-year; a persistent role in spirituality and ceremony, consistent use through cultural modernization; cannot be replaced in use; and provides opportunity for resource acquisition through commerce. Whether marula holds a powerful place in regional linguistics warrants complementary ethnolinguistic research. Marula is also

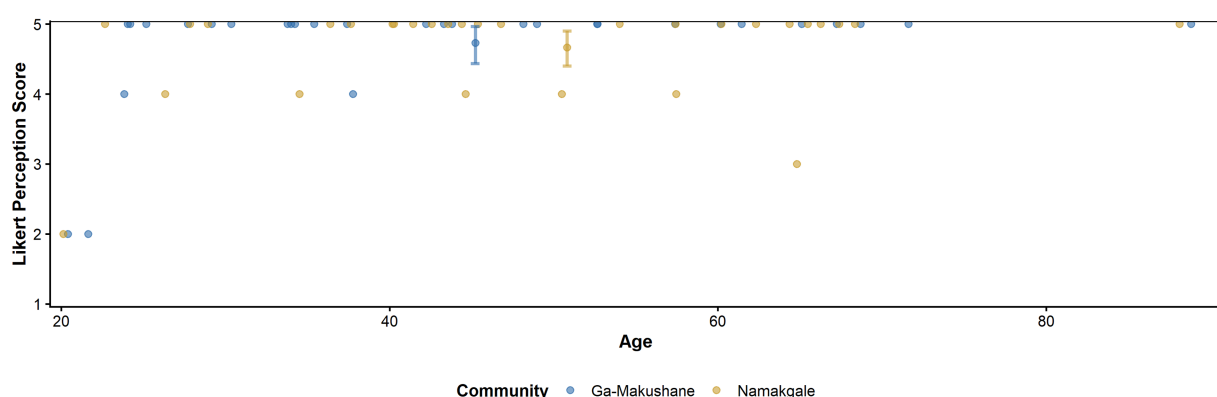


FIGURE 3

Relationship between respondent age and Likert perception score for the statement that respondents have a positive perception of local protected areas among 60 interviewees from two rural communities in Limpopo Province, South Africa. Scores range from 1 to 5, with higher scores indicating stronger agreement. Points show individual responses, colored by community.

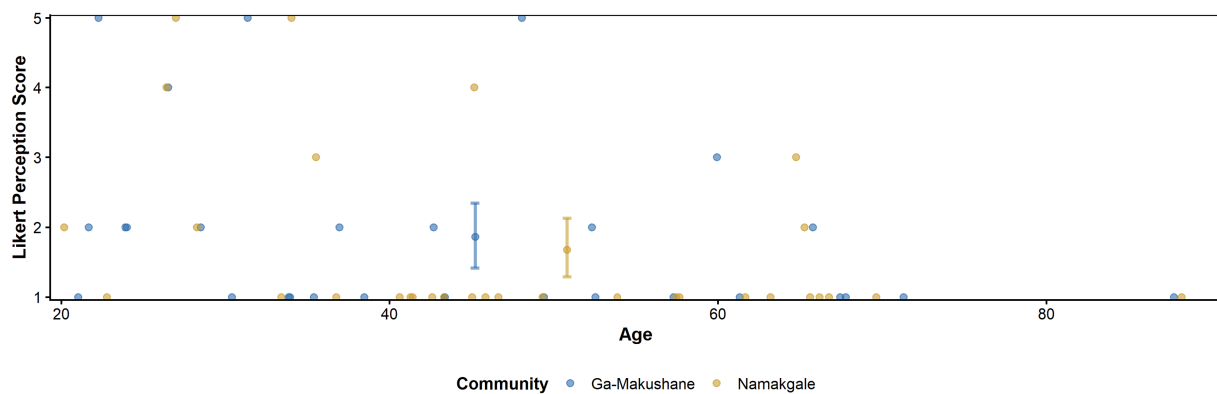


FIGURE 4

Relationship between respondent age and Likert perception score for the statement that elephants should be managed via culling to protect marula trees among 60 interviewees from two rural communities in Limpopo Province, South Africa. Scores range from 1 to 5, with lower scores indicating stronger disagreement and higher scores indicating stronger agreement. Points show individual responses, colored by community.

used spiritually and in rituals such as marriages and communicating with ancestors; serves as an important food staple throughout the year; and is abundant in the region. Community institutions and individuals are concerned with the protection and conservation of marula trees within and beyond their communities. Other studies have shown that marula trees have a positive influence on the lives and livelihoods of local communities (Sinthumule and Mzamani, 2019; Sinthumule and Mashau, 2019).

Similar findings have been observed in other regions with culturally significant species, such as the baobab tree (*Adansonia digitata*), which provides food, medicine, and cultural value (Sidibé and Williams, 2002). We suggest that our results strengthen and locally substantiate earlier suggestions that marula can be understood as a cultural or biocultural keystone species, while also indicating that fuller evaluation still requires complementary ethnolinguistic work in relation to Garibaldi and Turner's CKS criteria. This would facilitate several advantages for marula conservation: first this designation and subsequent research efforts will help reinforce the relationships between communities in the region and local protected areas (Garibaldi and Turner, 2004). Next, this would lead to a better understanding of whether these communities are experiencing environmental change (ex. climate change, reduced marula abundance, etc.) and how this affects the communities' resilience and resource demands (Garibaldi and Turner, 2004). Once local communities' connections to their landscape are reinforced through the conduit of species that are highly important to them, they will likely desire to play a more active role in ecosystem conservation (Garibaldi and Turner, 2004; Berkes, 2009; Fabricius et al., 2004). In the communities we sampled, there is already a desire to protect marula trees within and beyond the community boundary—therefore, much local support exists for further investment into marula conservation and management.

Older interviewees reported more positive perspectives on local protected areas, which may reflect generational differences in lived experience, including longer-term familiarity with protected areas, changing historical relationships with conservation institutions, or differences in how benefits and restrictions associated with protected areas are perceived. In Europe, older individuals are more open to financially supporting protected areas (Zydrón et al., 2021). In Nigeria, NTFP utilization alleviated some effects of poverty, although younger participants were more skeptical that the enterprise could support their livelihoods (Ganiyu et al., 2024).

Interviewees demonstrated strong support for marula conservation, as 57 of 60 respondents (95.0%) agreed or strongly agreed that marula trees should be protected wherever they are found and all respondents (100.0%) supported conserving marula in protected areas, highlighting a favorable social context for community-engaged marula conservation efforts (Makindi, 2016; Vodouhè et al., 2010). The majority of respondents reported avoiding harmful fruit-harvesting techniques and recognized local taboos or laws against damaging marula trees, with 59 of 60 interviewees (98.3%) agreeing or strongly agreeing that they do not cut branches when harvesting fruit and 53 of 60 (88.3%) agreeing or strongly agreeing that traditional laws or taboos in their community prohibit cutting marula trees. Cultural taboos and restrictions commonly affect how NTFP are used and managed (Ahenkan and Boon, 2010). This suggests that conserving marula is pivotal for maintaining the cultural beliefs, practices, and the resources it provides.

Despite broadly positive perceptions of marula, this support did not always translate into equally strong conservation engagement or awareness: although 37 of 60 interviewees (61.7%) agreed or strongly agreed that they work to plant and protect marula seeds and seedlings, only 32 of 60 (53.3%) reported being aware of declining marula populations in protected areas, suggesting that favorable attitudes toward marula were stronger and more widespread than awareness of its broader conservation challenges. Though marula appears abundant in these communities, increasing strain on the resource or changes in resource preference could lead to a marula population decline (Blair et al., 2021). Practical management recommendations emerging from this work include the establishment of community-based marula nurseries and seedling planting programs, integration of marula conservation messaging into existing cultural events such as the Namakgale Marula Festival, and co-management initiatives linking local harvest practices with protected-area restoration efforts. Such interventions are low-cost and align with demonstrated community support for marula conservation. Cultivation of marula is easy by seed, cutting and grafting (Department of Agriculture, Forestry, and Fisheries, 2010). Seeds have high enough germination rates and seedlings are resilient if kept well-watered and out of direct sunlight (Department of Agriculture, Forestry, and Fisheries, 2010; personal experience).

Medicinal use of marula: Twenty-six interviewees (43.33%) in this study reported using marula medicinally. Among those who did report medicinal use, bark, fruit, roots, and leaves were identified as therapeutic plant parts, and reported applications included gastrointestinal

complaints, pain and inflammation, infections, and post-partum care. These reported uses are broadly consistent with published pharmacological work on *Sclerocarya birrea*, including experimental evidence for anti-inflammatory effects, hypoglycemic or anti-diabetic activity, and antimicrobial activity against *Helicobacter pylori*, although this evidence is derived primarily from laboratory and animal studies rather than routine clinical use in humans (Ojewole, 2003a; Ojewole, 2003b; Ojewole, 2004; Ojewole et al., 2010; Njume et al., 2011; Mariod and Abdelwahab, 2012; Kokwaro, 2009). Collectively, these findings indicate that medicinal use of marula remains meaningful in our study communities, though not universal, and supports continued attention to both marula's cultural importance and its efficacy in traditional medicine. From a conservation and management perspective, these findings indicate that marula is not only ecologically important, but also socially and medicinally valued within local communities. Management strategies affecting marula populations should therefore account for the species' continued role in local health practices and consider how declines in marula availability could reduce access to culturally familiar medicinal resources.

Culling elephants to protect marula trees in protected areas: Culling elephants as a strategy to protect marula trees was unpopular across both communities. Interviewees were often taken aback when culling elephants (or increasing hunting of elephants) as a strategy to protect marula trees in protected areas was mentioned (Slotow et al., 2021). One of the most impactful strategies for developing acceptance of protected areas in local communities is to include community participation in the management of those protected areas (Andrade and Rhodes, 2012). Communities that feel maligned are likely to resist protected area regulations, protest against them, and refuse to cooperate with authorities, undermining both the institution of a protected area and the wellbeing of the biodiversity protected within it (Holmes, 2013). Including local communities in protected area management decisions may develop a sense of stewardship, leading to increased success in biodiversity conservation (Horowitz, 1998). Understanding the culture, welfare, and motivators for communities adjacent to protected areas is critical for successful biodiversity conservation (Andrade and Rhodes, 2012). Protected areas falter in the face of local opposition and disaffected communities have the ability to make protected areas fail (Brockington, 2004; Holmes, 2013; Makindi, 2016; West and Brockington, 2006). Many protected areas in Sub-Saharan Africa struggle in acquiring funding for conservation initiatives; logically, these protected areas should desire to assist and facilitate relationships development with their local communities.

Placing these results in a broader context: Respondents in both communities viewed marula as economically, culturally, and personally important. The multifunctional importance of marula in our study is consistent with broader global evidence that NTFPs often serve overlapping subsistence, economic, and cultural roles (Shackleton et al., 2025; Heubach et al., 2011). Over a billion people depend on forests for their livelihoods directly (Pandey et al., 2016).

In Southern Africa, rural households often use multiple NTFP to fulfill their needs (Shackleton et al., 2025; Shackleton and Shackleton, 2004). Further, though some of the resources that marula produce are seasonal (ex. fruit), income from marula beer largely comes in the post-Christmas season, when household funds may be low and funds are needed for school fees and supplies (Shackleton and Shackleton, 2004). Our results fit a broader pattern in which multifunctional NTFPs support livelihoods, especially where they provide culturally familiar and seasonally important resources (Shackleton and Shackleton, 2004; Shackleton et al., 2025).

Garibaldi and Turner (2004) presented several examples of cultural keystone species that fit their diagnostic criteria (and the diagnostic criteria used in this study) including: Western red-cedar (*Thuja plicata*), edible red laver seaweed (*Porphyra abbottiae*), and Wapato (*Sagittaria* spp.); western red-cedar was presented as their "ideal candidate." For the people of coastal British Columbia, Canada, this species is utilized for its high-quality wood in making dugout canoes; it is seen as a sacred tree and gift from the creator; it is part of seasonal dance ceremonies; it is treated with special respect through rituals and harvesting practices, and it features in the creation myth for the First Nations People resident there (Garibaldi and Turner, 2004). Although marula occupies a different cultural and ecological context, our findings suggest a broadly similar pattern of multifunctionality and cultural salience: interviewees overwhelmingly agreed that marula has a positive effect on their community, has economic impact, is culturally important, and forms an important part of their lives, while many also described medicinal use, spiritual relationships, and social value associated with the species. Our contribution is therefore not simply to nominate marula as a candidate, but to show how that broader CKS framing is reflected in contemporary local perceptions and reported uses.

Data availability statement

The datasets generated and/or analysed during the current study are not publicly available because they contain information that could compromise participant anonymity. Data may be available from the corresponding author on reasonable request, subject to ethical and confidentiality restrictions. Requests should be directed to cbanotai@uwyo.edu.

Ethics statement

The studies involving humans were approved by University of Wyoming Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

CB: Project administration, Visualization, Formal analysis, Data curation, Methodology, Writing – review & editing, Writing – original draft, Investigation, Conceptualization. CS: Project administration, Supervision, Methodology, Writing – review & editing, Conceptualization, Resources. JK: Validation, Conceptualization, Project administration, Writing – review & editing, Supervision, Resources, Funding acquisition.

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Conflict of interest

The author(s) declared that this work 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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