Uses, Knowledge, and Management of the Threatened Pepper-Bark Tree (*Warburgia salutaris*) in Southern Mozambique

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Uses, Knowledge, and Management of the Threatened Pepper-Bark Tree (*Warburgia salutaris*) in Southern Mozambique. *Warburgia salutaris*, the pepper-bark tree, is one of the most highly valued medicinal plant species in southern Africa. Due to its popularity in folk medicine, it is overexploited in many regions and is deemed threatened throughout its range. We identified cultural and social drivers of use, compared knowledge distribution, determined management practices, and explored local ecological knowledge related to the species in the Lebombo Mountains, Tembe River, and Futi Corridor areas in southern Mozambique. Stratified random, semistructured interviews were conducted (182), complemented by 17 focus group discussions in the three study areas. *W. salutaris* was used medicinally to treat 12 health concerns, with the bark being the most commonly used part. Knowledge of the species varied between the three areas, but not with respondent gender or age. Harvesting was mostly through vertical bark stripping (71% of informants). To promote sustainable use of the species, we suggest multiple conservation approaches, including the use of alternative species with the same application, substitution of bark by leaves, and increases in alternative sources of plant material through cultivation. Additional information on species demography, harvest impact, and post-harvest bark recovery rate area is required. Information obtained in this work can contribute to management guidelines and plans for the species in Mozambique.

Key Words: Folk medicine, gender, local ecological knowledge, quantitative ethnobotany, threatened species, trade.

Introduction

Lack of access to modern medical facilities and experts is one factor associated with the continued use of traditional medicine in developing countries. In sub-Saharan Africa, for example, the ratio of traditional medicine practitioners to population is 1:500, compared to 1:40,000 for general physicians (Abdullahi 2011). Even where modern medical facilities are available, many medicinal plant species remain in popular demand for cultural, traditional, and financial reasons (Bach et al. 2014). Demand for such species is increasing with population growth due to their high cultural recognition and often relatively low cost of acquisition compared to contemporary pharmaceuticals (Cunningham 1993; Maroyi 2013).

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Agrarian communities in developing countries often have unreliable sources of income and therefore engage in diverse livelihood strategies, such as the use of wild species for subsistence, cultural observances, and income generation (Ghorbani et al. 2012; van Wilgen et al. 2013). The range of species collected and the amounts harvested depend on species availability and access (Silva et al. 2018) and local and market preferences (Mukamuri and Kozanayi 2014), as well as traditions and culture (Franco-Maass et al. 2019; Sylvester and Alvaro 2009). In some contexts, such dependence generates sustainable harvesting practices to maintain species populations, which thereby contributes to improving people's well-being (Lima et al. 2013; Opperman et al. 2018; Shackleton et al. 2015; Stanley et al. 2012). However, in some instances, the use of wild species translates to unsustainable consumption through overexploitation, often motivated by economic incentives from trade (Botha et al. 2004; Sylvester and Alvaro 2009).

Although in some settings medicinal plants are associated with home garden cultivation or other anthropogenic habitats (Voeks 2004), in sub-Saharan Africa, most medicinal plants are harvested from natural habitats (Cunningham 1993), with very few derived from cultivated sources (Botha et al. 2004; Maroyi 2013). In some instances and under weak governance, harvesting from wild populations may pose conservation challenges for the targeted species, as well as co-occurring biodiversity, habitat integrity, and ecosystem processes (Kideghesho 2009; Shackleton et al. 2018). In Africa, resource use in the historical past was sustainable for most species, due to low human populations and low demand, along with traditional approaches based on social and cultural values (Cunningham 1993). However, growing human populations and commercial demand are undermining the viability of traditional practices for some species (Botha et al. 2004), especially those characterized by narrow distributions, small populations (Moyo et al. 2015), slow growth rates (Zschocke et al., 2000), constrained recruitment and sensitivity to land use pressures such as fire (Botha et al. 2004), and browsing (Kouki et al. 2004). Persistence of unsustainable practices will likely result in the local or regional loss of some medicinal species in high demand, thereby negatively impacting the very basis of primary health care for millions of people (Giday et al. 2003).

A number of strategies are available to manage and conserve species in high demand. In particular, for culturally important species such as medicinal plants, integration of local ecological knowledge (LEK) and practices into management strategies is important to foster common visions, goals, and compliance. Local ecological knowledge, defined here as information, practices, and principles, accumulated and transmitted through generations, based on observation and interaction with the natural environment, has been used to support community-based management of species and sites (Charnley et al. 2007). This includes a variety of approaches such as rotational harvesting to avoid overharvesting to allow for regeneration, selective harvesting of only mature individuals and allowing time for regeneration (Terer et al. 2012), and regulating harvesting time according to critical life phases of the species (Schmidt and Ticktin 2012). Additionally, substitution of species with the same application provides alternatives for treatment (Albuquerque and Oliveira 2007) and may ease the pressure on certain species. For example, the use of *Paris forrestii* (Takht.) H.Li. in place of *Paris polyphylla* var. *yunnanensis* (Franch.) Hand.-Mazz. for anti-cancer treatment and the replacement of a traditional papyrus, *Cyperus madagascariensis* (Willd.) Roem. & Schult., by invasive *Eichhornia crassipes* (Mart.) Solms for handicraft have been reported by Wang et al. (2018) and Rakotoarisoa et al. (2016), respectively. It is frequently assumed that the greater the reliance on a particular species, the greater will be the motivation for valuing the species and the deployment of local ecological knowledge to underpin sustainable uses (Ghorbani et al. 2012; Terer et al. 2012).

Warburgia salutaris (G.Bertol.) Chiov. (Canellaceae), commonly known as the pepper-bark tree, is a protected medicinal species in high demand in eastern and southern Africa (van Wyk and Wink 2004). The tree is generally 5 to 10 meters (m) tall but occasionally grows up to 20 m. The species occupies evergreen forests, wooded ravines, and bushveld (Coates-Palgrave 2002). It is used to treat a number of ailments including the common cold, sinus and chest complaints (van Wyk and Wink 2004), inflammation of the gums, throat problems, and mouth sores (Jansen and Mendes 1990). The active compounds (drimanes and sesquiterpenoides) are mostly found in the inner part of the stem and root bark. Additionally, the peppery aroma of *W. salutaris* leaves makes them an attractive condiment for different food dishes and beverages (Venter and Venter 1996). Due to the high demand for pepper-bark, it is regarded as highly threatened throughout its southern African range (Botha et al. 2004), driven by local subsistence uses and high commercial demand in urban centers.

Despite the high demand for the species, its ecology, local knowledge, and management are not well understood. Research has been centered on its medicinal uses (e.g., Maroyi 2013, 2014; van Wyk and Wink 2004), on the potential of the chemically active compounds in treating fungal (Samie and Mashau 2013) and bacterial (van Wyk and Wink 2004) infections, and on informal trade (Krog et al. 2006; Mander et al. 2006). In comparison, assessments of population status and local knowledge are limited, and none have been done in Mozambique. Botha et al. (2004) compared the status of populations in protected and nonprotected areas in Mpumalanga, South Africa. Mirroring the situation with many tree species that are subjected to high demand for bark, ring-barking (peeling of a bark strip embracing the whole stem circumference [Delvaux et al. 2010]) is common among *W. salutaris* populations. Recently, Dludlu et al. (2017) surveyed the status of populations throughout Swaziland, reporting widespread ring-barking, even in protected areas, but they also discovered several hitherto unknown populations. Mukamuri and Kozanayi (2014) attributed such destructive practices within communal lands to the ineffectiveness of institutional structures for the management of natural resources, including, but not limited to, lack of tenure and economic hardship in Zimbabwe. Veeman et al. (2014a, b) focused on the economics of the species in Zimbabwe. The first work found few, isolated, and small-scale markets for medicinal bark species, including *W. salutaris*. The second study suggested that under high bark production due to reintroduction of the species and favorable prices, the species would be able to sustain high economic returns. Moreover, Williams et al. (2014a) determined the bark area, volume, and mass traded for six overharvested medicinal bark species, including *W. salutaris* in South Africa, and concluded that bark mass (available bark) was directly proportional to the size of the stem. Through data on bark thickness from a market survey in Johannesburg, South Africa, Williams et al. (2014b) reported a decrease between 1995 and 2001 in the number of trees harvested for bark supply and changes in the availability of bark from large individuals. There have been, however, no studies of the LEK of *W. salutaris* nor of the local perceptions of factors that influence its population status.

Conservation initiatives are unlikely to succeed without the cooperation of local communities on whose land the populations are found. Thus, communities need to be integrated into strategies for managing supply and demand for pepper-bark. Long-standing cultivation initiatives in this region include (1) the supply of numerous cuttings for cultivation by traditional medicine practitioners and herbalists from the Silverglen nursery (Xaba and McVay 2010) and (2) research to identify efficient propagation methods for the species in and around Kruger National Park, where over 40,000 plants from seeds were made available for distribution (Hannweg et al. 2015). Such initiatives in South Africa also resulted in the reintroduction of cultivated material from South Africa to Zimbabwe (Maroyi 2012), and similar initiatives could also be established in southern Mozambique. With this in mind, we sought to (1) identify the uses of *W. salutaris*, (2) assess variations in use knowledge and LEK within the study areas and by respondent attributes, and (3) explore local management practices of *W. salutaris* in Mozambique.

Methods

Study Area

The study was conducted in 13 villages in Matutuine and Namaacha districts in Maputo Province, southern Mozambique, divided into three study areas: (1) the Lebombo Mountains (LM), (2) the Tembe River (TR), and (3) the Futi Corridor (FC) (Fig. 1). The climate is subtropical to tropical, with two main seasons: wet (October–April) and dry (May–September). The mean annual temperature varies from 21 to over 24 °C, and the mean annual rainfall varies from 600 to 1,000 mm (MAE 2005a, b).

W. salutaris in the Lebombo Mountains occurs on rocky slopes, where the vegetation varies with topography, soil depth, and aspect (Burrows et al. 2018). Common co-occurring species include *Acacia nigrescens* Oliv., *Acacia burkei* Benth., and *Combretum apiculatum* Sond and, on shallow soils, aloes, especially *Aloe marlothii* A. Berger, *Ficus* spp., and *Euphorbia* spp. *Olea africana* Miller and *Combretum* spp. are common species found on steeper and stony slopes (Kirkiwood 2014). The vegetation of the Tembe River area is different, being primarily sand forest. Dominant species include *Pteleopsis myrtifolia* (Laws.) Engl. & Diels,

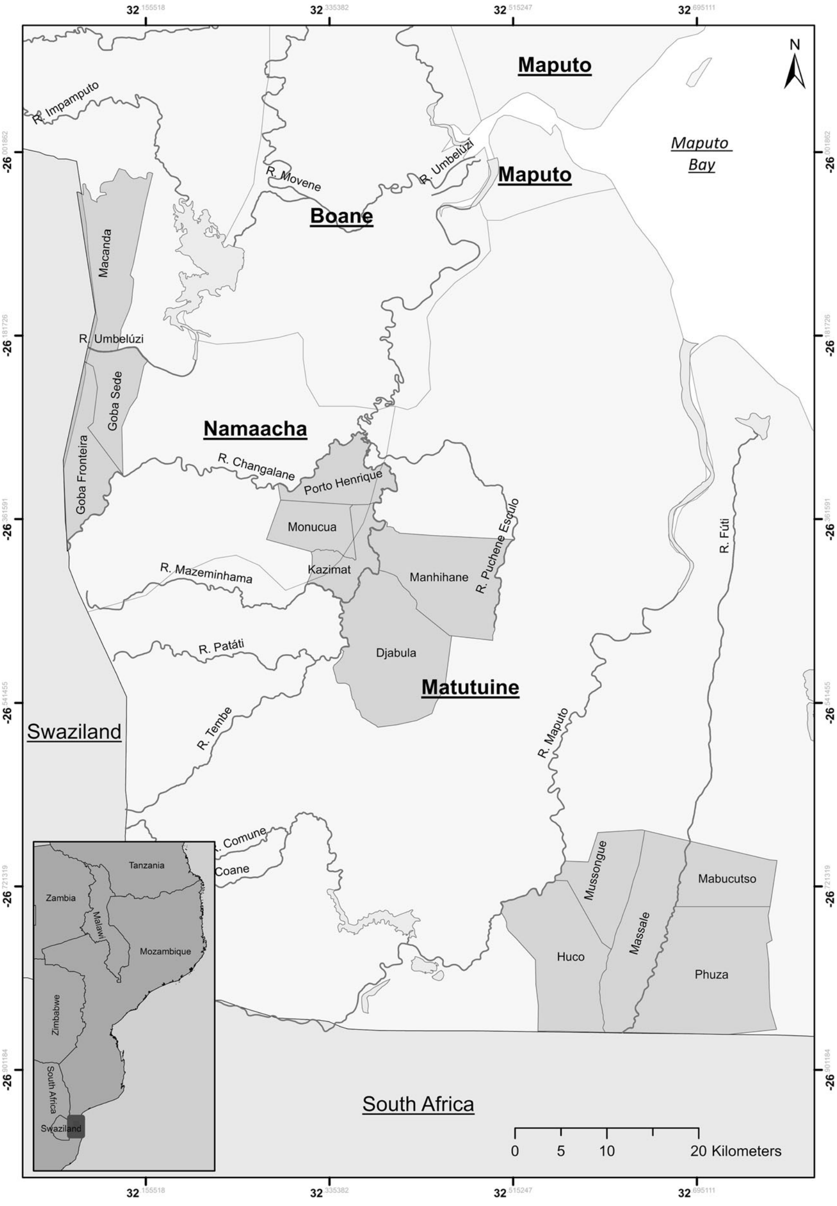

Fig. 1. Location of the Lebombo Mountains, Tembe River, and Futi Corridor areas and their respective villages in southern Mozambique.

Cleistanthus schlechteri Pax (Hutch.), *Hymenocardia ulmoides* Oliv., and *Monodora junodii* Eng. & Diels (Izidine 2003). Connecting patches of sand forest across Maputaland is open savanna woodland, characterized by *Strychnos* spp., *Terminalia sericea* Burch. ex DC., *Acacia burkei* Benth., *Combretum molle* R. Br. ex G. Don, and *Albizia versicolor* Welw. ex Oliv. (Moll 1980). In the Futi Corridor, *W. salutaris* is found near seasonal pans (MITUR 2002). The vegetation structure in this area is thicket, linked to termitaria with clay soils (Matthews et al. 2001). Common tree species include *Berchemia zeyheri* (Sond.) Grubov, *Pappea capensis* Eckl. & Zeyh., and *Olea europaea* subsp. *africana*

(Miller) P.S. Green and shrubs such as *Zanthoxylum capense* (Thunb.) Harv. and *Carissa bispinosa* L. Desf. (van Rooyen 1983).

The local inhabitants are primarily of Ronga ethnicity, although there is increasing in-migration of other ethnic groups. The main economic activities are subsistence, arable agriculture, and livestock rearing, along with commercialization of nontimber forest products (including fuelwood), and migrant labor to South Africa (GDM 2008; INE 2013a, b). Human population densities are low (8 and 24.4 inhabitant/kilometer (km)^2 for Matutuine and Namaacha districts, respectively), as are education levels (adults illiteracy rate in Matutuine is 42% and in Namaacha it is 31%) (INE 2015) and formal employment opportunities (GDM 2008).

Data Collection

Authorization for the research was granted by traditional and local leaders, as well as ethics approval by the departmental committee at Rhodes University (November 2015). Prior informed consent was obtained from respondents before conducting interviews. A stratified random sampling procedure was employed to select people who knew the species. Household interviews were carried out in (1) Tembe River (Manhihane, Djabula, Kazimat, Porto Henrique, and Monucua villages), (2) Futi Corridor (Huco, Mussongue, Massale, Mabucutso, Phuza), and (3) Lebombo Mountains (Goba Sede, Goba Fronteira, and Macanda villages). Sixty to 62 interviews per study area (182 in total) with the heads of households were conducted between April and September 2016. The questions asked respondents to identify (1) cultural and social aspects of *W. salutaris* use, including reasons for use and parts used, substitute species, restrictions, and demands for the species; (2) uses and knowledge by informant gender and age; (3) local management practices; and (4) the LEK, comprising habitat preferences and phenology. Past and expected trends in local abundance and status were considered: (1) before the civil war (1977); (2) after the civil war until the present (1992–2015); and (3) into the future (2016+). Demographic information of each informant was recorded, such as age, gender, and origin (born in the region or immigrant). Additionally, we conducted one or two focus group discussions per village (17 in total) with five to seven key informants identified by local traditional leaders to explore in-depth knowledge of any pertinent issues that were raised during the household interviews.

Data Analysis

Following Phillips and Gentry (1993), we calculated the species use value (UV) as the average number of uses identified by informants. Along with the use value, the informant's diversity index and informant's equitability index were computed (Byg and Balslev 2001; Monteiro et al. 2006), but as the three were highly correlated, the last two were not reported. Because the data were not normally distributed (Shapiro–Wilk test), nonparametric analyses were favored. Kruskal–Wallis and Mann–Whitney U tests were used to evaluate the differences between respondents in the three study areas. The Spearman correlation coefficient (rho) was employed to analyze the relationship between the use value and the age of informants. Based on the information synthesis from the focus group discussions, variables relating to the ecological information provided by respondents were coded in three response groups: no knowledge (score 0), elementary knowledge (1), and profound knowledge (2) (Ghimire et al. 2004; Ticktin and Johns 2002). A Kruskal–Wallis test was performed to evaluate the differences in LEK (reflected in the coded responses) between respondents in the three study areas. Statistical analyses were conducted using SPSS 20 and STATISTICA 13, at a significance level of 95%.

Results

Respondent Profiles

The respondent households were largely agrarian, with income supplemented by charcoal production and trade in the Lebombo Mountains and Tembe River areas and by palm wine production and sales in the Futi area. Formal education levels were low. The proportion of immigrants was low in the Futi Corridor, high in Lebombo Mountains, and intermediate in Tembe River (Table 1).

Uses, Demand, Restrictions, and Alternatives

Local Uses for the Species

All but one respondent (in FC, who said that local populations were too far away) reported using *Warburgia salutaris* for medicinal purposes, treating one or more of 12 health concerns. These included

TABLE 1. RESPONDENT CHARACTERISTICS IN THE THREE STUDY AREAS.

Attribute	LM ($n = 60$)	TR ($n = 62$)	FC ($n = 60$)	Mean
Age range (years)	23–72	22–72	22–76	46.2
Origin				
Indigenous	16	31	48	31.7
Immigrants[1]	44 (13)	31 (6)	12 (3)	29 (7.3)
Major household activities				
Agriculture	56	62	45	54.3
Charcoal production and sales	29	37	0	22
Permanent job	35	7	6	16
Palm wine production and sales	0	1	21	7.3
Education levels				
Illiterate	21	25	31	25.7
Primary education	38	37	27	34
Secondary education	1	0	2	1
Gender				
Female	29	24	12	22
Male	31	38	48	38.7

LM = Lebombo Mountains, *TR* = Tembe River, *FC* = Futi Corridor.
[1] The number of people who moved into the area during the civil war is in brackets.

respiratory tract ailments (cough, asthma, and the common cold), digestive tract ailments (mouth and throat sores, dysentery, stomachache, and hemorrhoids), fortification of children, fevers, headaches, body pains, and malaria. *W. salutaris* was mainly used for coughs (71.4% of households) and for mouth and throat sores (61%) (Table 2). Out of the 12 ailments, 10 were mentioned in TR, nine in FC, and eight in LM.

Bark was the most widely used part of the tree (92.2% of households) (Table 2). Of the 182 respondents, 69.2% used only the bark and 14.3% used bark and leaves. Bark was employed in the treatment of 11 ailments except for fortification of children. Leaves and roots were each used for the treatment of nine ailments (including the recurring ailments in the study areas) but were not commonly used (22% households used leaves and 12% roots) (Table 2).

TABLE 2. PLANT PARTS USED FOR SPECIFIC HEALTH CONCERNS BY RESPONDENTS IN THE THREE STUDY AREAS.

Health concern	Bark (% resp.)	Leaves (% resp.)	Roots (% resp.)	Branches (% resp.)	Trunk (% resp.)	No. of parts used
No. of ailments	12	9	9	1	3	–
Households using that part	92.2	22	12	0.5	0.5	–
Asthma	4.9	2.2	1.1			3
Common cold	1.1	0.5				2
Body pains	3.2	0.5	0.5	0.5		4
Cough	71.4	9.9	4.4		0.5	4
Dysentery	1.1					1
Fever	1.1	7.1				2
Fortification			1.1			1
Hemorrhoid	14.3	1.6	2.2		0.5	4
Headache	5.5	1.6	0.5			3
Malaria	1.1		0.5			2
Mouth and throat sores	61	4.4	3.8		0.5	4
Stomachache	3.8	1.1	1.1			3

% resp. refers to the percentage of respondents except in the no. of ailments and no. of parts used.
No. = number.

Alternative Species

Fifty-one species were mentioned as possible substitutes for *W. salutaris*, each treating from one to four ailments. The LM area had the most alternative species (37), followed by TR (33 species), and FC (17 species). The most mentioned alternative species in the LM were *Sclerocraya birrea* subsp. *caffra* (A.Rich.) Hochst. and *Citrus limon* (L.) Osbeck. In the TR, they were *Terminalia sericea*, *S. birrea*, *Eucalyptus camadulensis* Dehnh., and *Anacardium occidentale* L., and in the FC, "macuene" (an unidentified species) and *Ficus* sp. All the health problems mentioned had plant substitutes for treatment, and the most common health problems had several alternative species (e.g., cough 44 species, mouth and throat sores 19, and hemorrhoids 15).

Harvesting Restrictions and Demands

Almost equal proportions of respondents said that there were (39%) or there were not (43%) any restrictions regarding who can collect pepper-bark. Households in the LM and the FC harvested less due to the long distances to collection grounds, i.e., 0.2 to 5.1 km in LM and 0.5 to 14.2 km in FC, compared to 0.006 to 2.6 km in TR, where the species was mostly found relatively close to homes. The presence of elephants in the Futi Corridor was an additional concern to harvesters. About 71% of households harvested *W. salutaris* themselves (98.4% TR, 63.3% FC, and 50% LM), whereas 16.5% acquired it from other community members (33.3% LM, 15% FC, and 1.6% TR), and the rest used a combination of procurement means, i.e., (1) markets or other community members, (2) markets or self-harvesting, and (3) other community members or self-harvesting.

Most respondents said that there was no specific season (66.5% in the rainy season and 65.9% dry season) or time of the day (71.4%) for harvesting. Approximately half (51.1%) indicated there were no areas where harvest is restricted, whereas 19.2% said there are some zoning restrictions. The remaining households were unaware of spatial harvesting restrictions. Quantities harvested by most households (72.5%) were very small, as were the quantities used, mostly a finger-sized piece of bark (56%), and harvesting was infrequent.

Of the 182 respondents, only 2.2% reported currently selling pepper-bark. However, 10.4% did so in the past but are no longer selling it (Table 3). Those who were currently selling were from FC (6.7%), and those who sold it in the past were from the TR (14.5%), FC (10%), and LM (6.7%). However, 12.1% of the respondents were not sure about the involvement of other household members in trade of the species (8.3% of LM respondents, 8.1% of TR, and 20% of FC). The existing trade was done more than twice a week by traditional medicine practitioners (1.1% of FC respondents), and of the remaining less than twice a year. The amount of bark currently sold varies from one teaspoonful (3% of the FC respondents), four pieces (equivalent to a palm size piece), and three bags of 50 kg, in each case cited by a single format.

Slightly less than one-third (30.8%) of respondents said that they knew someone who used to be involved in the trade (that is 35.5% TR respondents, 31.7% FC, and 25% LM), but 56% claimed not to know anyone that traded in the past. Approximately half of the respondents (51.1%) stated that currently, no outsiders from other communities come to collect *W. salutaris* bark in their area—TR (67.7%), LM (60%), and FC (25%). The presence of collectors from outside the communities cited by 30.2% of respondents was largely mentioned in FC (56.7%). Those who pointed to external collectors (24.2% of respondents) knew their provenance (46.7% from FC, 21% from TR, and 5% from LM). Of those who reported knowing the provenance of outside collectors, 21.7% mentioned that people were coming sometimes (once in three or more months per year) to collect in FC, 16.1% from TR, and 1.7% from LM. Those who reported regular collections by outsiders (once a month) all were from FC (20%), and those who came rarely (once in two or more years) were few (varying from 3.3% in LM to 8.1% TR) in the study areas (Table 3). People coming to collect in LM and TR were reported to be family members from adjacent communities.

Use Variation According to Area, Gender, and Age

The average number of uses identified by informants (use value) for pepper-bark differed significantly between the three areas ($H = 17.3$; $p < 0.05$), mostly between the Tembe River and the Futi Corridor. On average, households in the TR listed 2.3 ± 0.9 uses for *W. salutaris*, whereas those in the LM and FC mentioned 1.9 ± 0.7 and 1.6 ± 0.7 uses, respectively. The mean use value also differed between women in the three areas ($H = 14.24$,

TABLE 3. INVOLVEMENT IN BARK COLLECTION AND TRADE IN THE THREE STUDY AREAS.

Description	Response	% respondents			
		All ($n = 182$)	LM ($n = 60$)	TR ($n = 62$)	FC ($n = 60$)
Current trade	Yes	2.2	0	0	6.7
	No	97.8	100	100	93.3
Past trade	Yes	10.4	6.7	14.5	10
	No	77.5	85	77.4	70
	Do not know	12.1	8.3	8.1	20
Community members (past traders)	Yes	30.8	25	35.5	31.7
	No	56	60	59.7	48.3
	Do not know	13.2	15	4.8	20
	N/A	0	0	0	0
Other communities (collectors)	Yes	30.2	10	24.2	56.7
	No	51.1	60	67.7	25
	Do not know	18.7	30	8.1	18.3
	N/A	0	0	0	0
Origin[1] (other communities)	Yes	24.2	5	21	46.7
	No	3.8	1.7	3.2	6.7
	Do not know	2.2	3.3	0	3.3
	N/A	69.8	90	75.8	43.3
Frequency of collection	Regularly	6.6	0	0	20
	Sometimes	13.2	1.7	16.1	21.7
	Rarely	5.5	3.3	8.1	5
	Do not know	1.6	0	0	5
	N/A	73.1	95	75.8	48.3

LM = Lebombo Mountains, *TR* = Tembe River, *FC* = Futi Corridor.
[1] Refers to the provenance of nonlocal harvesters.

$p < 0.05$). Generally, female respondents in TR reported the highest values of 2.3 ± 1.0 and the FC the lowest (1.3 ± 0.5). Equally, the use value varied between men ($H = 9.3$, $p < 0.05$) in the three areas, with the highest value in the TR (2.2 ± 0.9) and the lowest in FC (1.7 ± 0.8). Within study areas, men had higher use values than women (2.1 ± 0.7 men and 1.9 ± 0.7 women in LM, 2.2 ± 0.9 and 2.3 ± 1.0 TR, 1.7 ± 0.8 and 1.3 ± 0.5 in FC), but the difference was significant only in the LM ($p < 0.05$).

There was no statistical correlation between informant's age and the use value ($p > 0.05$) in the three areas. The Spearman correlation coefficient (rho) was 0.212 in the LM, − 0.002 in FC, and − 0.116 in TR.

HARVESTING METHODS AND MANAGEMENT

Three harvesting practices were reported. These included discontinued vertical strips (bark stripping on the length of trunk) mentioned by 71.4% of respondents (100% from TR, 61.7% FC, and 51.7% LM), ring-barking (0.5% corresponding to 1.7% of LM respondents), and cutting of branches (1.1%). Most people only used a machete (64.3%), corresponding to 98.4% from TR, 517% FC, and 41.7% LM, while other instruments (axes, stones, and knives), separately or together, were rarely used (ranging from 0 to 5% of respondents). Bark was most typically harvested from the middle of the tree trunk.

Most respondents (58.8%) knew methods of bark harvesting that reduced damage to the plant, especially in the Tembe River (Table 4), including taking noncontinuous vertical strips (17.8%), harvesting only small quantities (16.1%), and superficial wounds (13.9%). Less frequently mentioned harvesting approaches included not harvesting at the base of the stem (3.3%), rotational harvesting (1.1%), and using a knife (0.5%).

Approximately two-thirds (64.8%) of the respondents could identify harvesting approaches that result in significant damage to plants, ranging from 50% in the Lebombo Mountains and the Futi Corridor to 91.1% in the Tembe River (Table 4). The method that was considered to be most damaging was ring-barking (54.8%). Other procedures mentioned less often included deep wounds (8.8% of respondents), harvesting large quantities

TABLE 4. HARVESTING AND CONSERVATION PRACTICES FOR PEPPER-BARK TREE (*W. SALUTARIS*) (% OF RESPONDENTS).

Description	Response	% of respondents			
		All (n = 182)	LM (n = 60)	TR (n = 62)	FC (n = 60)
Less damage (methods)	Yes	58.8	48.3	75.8	51.7
	No	1.1	3.3	0	0
	Do not know	18.7	6.7	24.2	25.0
	N/A	21.4	41.7	0	23.3
More damage (method)	Yes	64.8	50.0	91.9	51.7
	No	1.1	1.7	1.6	0
	Do not know	12.6	6.7	6.5	25.0
	N/A	21.4	41.7	0	23.3
More damage (season)	Yes	18.7	13.3	19.4	23.3
	No	36.8	30.0	66.1	13.3
	Do not know	21.4	15.0	14.5	35.0
	N/A	23.1	41.7	0	28.3
Specific conservation action	Yes	38.5	26.7	59.7	28.3
	No	41.2	35.0	40.3	48.3
	N/A	20.3	38.3	0	23.3
Cultivation	Yes	6.6	6.7	1.6	11.7
	No	93.4	93.3	98.4	88.3
Conservation importance	Yes	98.9	100.0	100.0	96.7
	No	0	0	0	0
	Do not know	1.1	0	0	3.3

LM = Lebombo Mountains, *TR* = Tembe River, *FC* = Futi Corridor.

(13.7%), repeat harvests (1.1%), and harvesting from small trees (1.1%). Even though conservation of *W. salutaris* was viewed as important by almost all of the respondents (93.4%), many (41.2%) reported an absence of specific actions to conserve the species (Table 4). Equally, very few households (6.6%) cultivated the species in their home gardens. However, some households (38.5%) mentioned existing measures related to the conservation of the species, including harvesting approaches (stripping small quantities, noncontinuous vertical stripping) strictly for household use, avoiding uncontrolled fires, and investing in on-farm conservation (varying from 6 to 11% of respondents). Most of these (59.7%) were from the TR (Table 4).

LOCAL ECOLOGICAL KNOWLEDGE

Knowledge related to the various ecological niches favored by *W. salutaris* varied significantly between the three areas. In almost all cases (except nonhabitat characteristics and reasons behind changes in abundance after the civil war), the Tembe River communities demonstrated more knowledge than the other two areas (Table 5).

Respondents mentioned 17 characteristics that described the favored habitats for *W. salutaris*. The variation in knowledge was mainly in terms of soil texture, color and fertility, occurrence near water bodies, shady areas, rocky substrates, lowlands, mountains, and termite mounds. Many households (50.5%, ranging from 21.7% in LM to 77.4% in TR) mentioned clayey soils as the main characteristic, followed by areas situated near water courses (22.5% corresponding to 25% from FC, 24.2% TR, and 18.3% LM), and black soils (19.8%), mainly from TR (41.9%). Eleven conditions were mentioned as being avoided by the species, but 43.9% of the informants had no knowledge in this regard. The main characteristic reported was sandy soils (34%), mainly by the FC informants (60%).

Very few respondents (8.2%) in the three study areas had knowledge of the flowering time of *W. salutaris*, with the highest response from TR. In addition, potential pollinators, mostly bees, were identified by very few people (16.5%), also with the highest response from TR.

More than half of the respondents (54.4%) across the three areas stated that the abundance of *W. salutaris* had declined in their areas (ranging

TABLE 5. MEAN SCORES (+ SD) OF LOCAL ECOLOGICAL KNOWLEDGE OF *WARBURGIA SALUTARIS* IN THE THREE AREAS (*N* = 182) AND COMPARISON OF SCORES BETWEEN THE RESPONDENTS IN THE THREE AREAS (*P* VALUE).

Variable	All (scores mean ± SD)	LM (scores mean ± SD)	TR (scores mean ± SD)	FC (scores mean ± SD)	*p* value
Habitat characteristics	0.8 ± 0.5	0.7 ± 0.7	1.0 ± 0.3	0.8 ± 0.4	0.0017
Nonhabitat characteristics	0.5 ± 0.5	0.4 ± 0.5	0.3 ± 0.5	0.7 ± 0.5	0.0004
Flowering month	0.2 ± 0.6	0.1 ± 0.4	0.4 ± 0.8	0.0 ± 0.3	0.003
Pollinators	0.3 ± 0.7	0.2 ± 0.6	0.7 ± 1.0	0.1 ± 0.4	< 0.0001
Status (post-civil war)	1.1 ± 1.0	0.8 ± 1.0	1.5 ± 0.9	1.0 ± 1.0	0.0001
Reasons (abundance post-civil war)	0.7 ± 0.8	0.5 ± 0.7	0.8 ± 0.4	0.9 ± 1.0	0.0039
Future trends	1.1 ± 0.9	0.7 ± 0.9	1.6 ± 0.7	1.1 ± 1.0	< 0.0001
Reason (future trends)	0.7 ± 0.6	0.5 ± 0.6	0.9 ± 0.5	0.7 ± 0.7	0.0001
Drought sensitivity	1.4 ± 0.9	1.0 ± 1.0	1.8 ± 0.6	1.4 ± 0.9	< 0.0001

LM = Lebombo Mountains, *TR* = Tembe River, *FC* = Futi Corridor.

from 38.3% in LM to 75.8% in TR). Four drivers were identified as underpinning this perceived decrease, namely the bark trade (30.8%), cutting for charcoal production (22.5%), wildfires (12.6%), and opening up land for construction (0.5%). Approximately one-third of the respondents (37%), mostly from TR, felt that the abundance of the species was reduced by harvesting for charcoal and the bark trade. Additionally, 14.3% of respondents felt that the abundance was likely to decrease in the future, largely as a consequence of the bark trade (12.1%). Other reasons mentioned included prolonged drought (1.6%), exploitation for charcoal (0.5%), absence of harvest norms in the community, and scarcity of the species (0.5%).

Most people (70%) perceived *W. salutaris* to be drought tolerant relative to other tree species as a baseline for comparison. The TR communities were more knowledgeable than others (90.3%), while FC had 68.3% and LM 50%. This was based on the prolonged drought during the sampling period where some species lost leaves, and others died, but *W. salutaris* remained evergreen throughout the year even during a drought.

Discussion

USES, DEMAND, RESTRICTIONS, AND ALTERNATIVES

Local Uses for the Species

The results revealed 12 local medicinal uses for pepper-bark tree, including for common ailments such as colds, chest complaints, coughs, malaria, and headaches. The use of *W. salutaris* to treat these health problems has been widely reported in southern Africa (Jansen and Mendes 1990; Maroyi 2013, 2014; van Wyk and Wink 2004). In Kenya, *W. salutaris* is among the most valuable medicinal species for malaria treatment and is also used for chest complaints or pneumonia (Bussmann et al. 2006). Medicinal uses mentioned in this work corresponded to 36.7% of those reported for *Warburgia* genus in southern and eastern Africa (Maroyi 2014). Our results did not reveal any nonmedicinal uses for the species (e.g., fencing and for food) (Venter and Venter 1996), or ethnoveterinary remedies for treating livestock (Grande et al. 2009).

Almost all parts of the plant were used, with bark being the most preferred, as has also been reported elsewhere in southern Africa (c.f. van Wyk and Wink 2004). High demand for the bark in the region is regarded as the main cause for the decline of the species (Botha et al. 2004; Coates-Palgrave 2002). For example, out of 15 applications recorded in Zimbabwe, all but one used bark or roots, whereas in South Africa, 38 uses employing *W. salutaris* all used bark, in some cases in combination with leaves or roots (Maroyi 2014). Some authors argue that the substitution of bark by leaves could contribute to the conservation of the species (Zschocke et al. 2000). Generally, the use of leaves by the respondents was low, but they did cover a considerable number of ailments, including common ones. Consequently, as recommended by Zschocke et al. (2000), analysis of the chemical compounds and relative efficacy in different organs of the plant is required. Until then, it is worthwhile considering substitution of bark by leaves as one possible conservation strategy for *W. salutaris* in southern Mozambique. Involvement of traditional medicine practitioners will facilitate adoption of the strategy if they prescribe leaves instead of bark (Zschocke et al., 2000).

Alternative Species

Respondents reported many substitute species for *W. salutaris*, as has been reported for several other medicinal species of concern in different countries. For example, *Cryptocarya* spp. are used as substitutes for *Ocotea bullata* (Burch.) Baill. in South Africa (Zschocke and van Staden 2000), and in New York City, a number of species have been substituted in the traditional healing flora of Candomblé adherents (Fonseca and Balick 2018). The availability and use of alternatives is a potentially important conservation strategy to avoid or limit further population declines (Wang et al. 2018; Zschocke and van Staden 2000). However, challenges might be encountered because of people's beliefs around specific species which may constrain their willingness to adopt the measure. For example, the conviction of people in Zimbabwe about the superior medicinal value of *W. salutaris* makes it difficult to promote substitute species (Mukamuri and Kozanayi 2014), even though some alternative species may not necessarily be of lower quality. For example, *Cryptocarya* spp. (including rarely used species within the genus) are more effective than *O. bullata* and were qualified substitutes (Zschocke and van Staden 2000). Equally, in a list of substitute species for medicinal *Myracrodruon urundeuva* Fr. All., and in consensus of communities, *Anacardium occidentalis* was selected as a better substitute by two semiarid rural communities of northeastern Brazil (Monteiro et al. 2006). Our results revealed a considerable number of species that can be used to replace *W. salutaris*, e.g., *S. birrea* in LM, *T. sericea* in TR, and *Ficus* sp. in FC.

Harvest Restriction and Demand

The results indicated that there were no local restrictions in the three areas on who collects *W. salutaris*, the plant parts collected, harvesting season, and gathering time of day. However, more than half of the people in the Futi Corridor mentioned the existence of spatial harvesting restrictions in their area. The disagreement between the respondents on restriction of collectors could be explained by the long distance from the homestead to collection grounds in the Lebombo Mountains and Futi Corridor areas. Collection in these areas was normally done by men due to the long distance to collection sites, similar to the situation for men in the Caura River Basin (Venezuelan Guayanas) communities, who are working away from home (Souto and Ticktin 2012). However, in our study, this seems to be a case of spatial division of labor, having men working far from home in natural areas (Voeks 2007), rather than a restriction. Furthermore, human–elephant conflict is a problem in the study area, which also constrains access to species. Thus, only braver people with an understanding of elephant movement along the Futi Corridor might harvest nontimber forest products (NTFPs) in that region. In addition, community members traveling in vehicles on their way home from Phuza Fair (occurring twice a week) or from South Africa are reported to stop at times and harvest *W. salutaris*.

Spatial restriction of harvest was only mentioned in the Futi Corridor, which is a protected area established as an extension of the Maputo Special Reserve (GM 2011), with the aim of enhancing the protection of local wildlife, especially elephants. Although community members were aware of harvest restrictions, they have long been collecting in the area because *W. salutaris* is mostly confined to the immediate area. Some legally protected areas, like the Futi Corridor, serve to limit people's rights of access to traditional resources, even those who use traditional harvesting methods (Ward et al. 2017). On the other hand, credit needs to be given to informal institutions promoting and regulating sustainable use practices by encouraging voluntary compliance (Colding and Folke 2001). With the absence of cultural restrictions, the existence of spatial restrictions could be capitalized upon for protection of multiple species, including the target endangered species. However, it is challenging to spatially restrict harvesting for resources that are deeply embedded in local cultures and livelihoods (Kideghesho 2009). Further work on the population status and dynamics of *W. salutaris* could cast light on the effectiveness of the Futi Corridor as a protected area.

The results revealed that most respondents harvested only small amounts of plant material and relatively infrequently. Very few confirmed their own involvement or knew community members who were involved in the past or present trade of

W. salutaris bark. However, previous work in southern Africa (e.g., Botha et al. 2004; Krog et al. 2006; Mander et al. 2006) has reported extensive bark harvesting and trade networks. Mozambique is known to supply *W. salutaris* bark to urban medicinal markets of Maputo Province (Krog et al. 2006) and to neighboring countries (Mander et al. 2006; Veeman et al. 2014b). We acknowledge that there might have been some underreporting by the respondents in our survey as some may have worried about us informing authorities. Not surprisingly, underreporting and denial of involvement is common when investigating practices that are noncompliant with formal or informal regulations or laws (Jann et al. 2012; Tourangeau and Yan 2007). One way of investigating illegal activities is through asking questions in an indirect manner (Nuno and St. John 2014). For example, in this study, when exploring LEK, most respondents mentioned the bark trade as one of the primary drivers of current and likely future decline of the species in the study areas, but did not admit to personal involvement. This suggests that the bark trade is still practiced and is a potential threat in the study areas. Another possibility is that the bulk of the bark harvested and sold in the three areas is done by only a few individuals, representing only a very small proportion of the population and our sample. It is noteworthy that some respondents were involved in the trade in the past, but currently, the bark trade is reported only in the Futi Corridor. We suspect that past involvement was a partial consequence of the civil war in Mozambique, which undermined normal agricultural activities and livelihoods, and thus, many households turned to whatever means possible to survive, including trade in high value resources. It appears, however, that illegal trading still persists in Futi Corridor. A study on local livelihoods and incomes and harvest impact (bark damage) is required to shed more light on this.

Harvesting Methods and Management

Bark was the most frequently harvested part of the pepper-bark tree, normally through vertical strips removed from the middle of the stem using a machete. Most of the households could identify harvesting methods that they believed limited damage to the plant, as well as the opposite, i.e., harvesting procedures that could result in more damage to the harvested tree. Most respondents regarded ring-barking as the most inappropriate harvesting method as opposed to vertical stripping. This is because ring-barking results in removal of all the cambium, impeding the regrowth of living tissue around the wound that results in bark regeneration. With the removal of the inner bark, transportation of photosynthates from the leaves to the roots is blocked, ultimately causing plant death (Delvaux et al. 2010). Appropriate harvesting techniques can limit damage to the inner bark, allowing for bark regeneration (Pandey 2015; Stewart 2009). For example, regeneration of six medicinal tree species in India was improved if the inner bark was not harvested (Pandey 2015), as was the case with 12 species in Benin (Delvaux et al. 2010). This is because shallow damage to the bark is unlikely to affect the cambium (Baldauf et al. 2014; Romero 2014), and thus, still allows the flow of sugars from the leaves to the roots.

An alternative approach was the harvesting of only small areas of bark. This allows the bark to regenerate because only a small portion of the cambium is damaged. For this type of harvest, Chen et al. (2014) reported the formation of new periderm and wound cambium from callus, and the wounded cambium subsequently forms new phloem. The presence of cambium determines the survival of the tree, and the applied harvesting practices allow bark regeneration through preservation of the cambium. Therefore, work on the recovery rates of post-bark harvesting is important for recommendations of sustainable harvesting approaches (Delvaux et al. 2010; Pandey 2015).

Harvesting of other parts of *W. salutaris* was uncommon. However, according to Zschocke et al. (2000), bark and underground parts are some of the most used in South Africa. The authors suggested substitution by aerial parts, such as the leaves, to reduce the negative effects of harvesting. This would first require validation of the therapeutic efficacy of the leaves.

Although *W. salutaris* was viewed as an important resource by the surveyed households, there were very few deliberate actions to maintain trees or populations, and cultivation in home gardens was uncommon. Home gardens are most often used to produce fruit trees, vegetables, and herbaceous medicinal plants, rather than perennial medicinal trees (cf. Panyadee et al. 2018; Williams et al. 2018). Notable exceptions are usually multipurpose trees such as the drumstick tree (*Moringa oleifera* Lam.), the African baobab (*Adansonia digitata* L.), and African mahogany (*Khaya senegalensis* [Desv.] A.Juss.) (Agundez et al. 2018; Gandji et al. 2018; Gaoue and Ticktin 2007). The *in situ* cultivation of

W. salutaris practiced by a few community members in the study areas is done through transplanting suckers (root sprouts). For species of conservation concern, the use of suckers may be a strategy for widespread propagation and distribution, although it would need to be from multiple populations to maintain genetic diversity. Vegetative propagation of *W. salutaris* is also possible through tissue culture, as demonstrated in a large program in neighboring South Africa (Hannweg et al. 2015; Mbambezeli 2004). Additionally, *W. salutaris* is being cultivated *ex situ* in South Africa (Mbambezeli 2004), Zimbabwe (Veeman et al. 2014b), and Mozambique (personal observation), which would provide strong bases for possible cultivation. Moreover, the experience of reintroduction into its natural habitat in Zimbabwe (Veeman et al. 2014b) could also be capitalized for *in situ* home gardening in southern Mozambique. As elsewhere in the world, home gardening of native species for people living in close proximity to relatively intact habitats is uncommon because people can acquire products easily in the wild (Kujawska et al. 2018). Nevertheless, it is a potential practice for conservation of many species of concern that are important for subsistence or culture (Barbhuiya et al. 2016; Das and Das 2015; Huai et al. 2011). And the practice of cultivating medicinal wild species has been recommended elsewhere for species in high demand (e.g., Maroyi 2012; Moyo et al. 2015) including *W. salutaris*.

Local Ecological Knowledge

In this study, we used focus group answers as a benchmark to evaluate LEK between the three study areas rather than comparing it with scientific knowledge (Chalmers and Fabricius 2007; Steele and Shackleton 2010). Overall, levels of LEK were higher in the Tembe River for almost all the measures, followed by the Futi Corridor and the Lebombo Mountains. Although previous studies have revealed that different factors, such as age, gender, origin, and occupation underpin variations in LEK (cf. Naah and Guuroh 2017; Souto and Ticktin 2012), that was not the case in this study. Rather, higher LEK is likely the result of increased frequency of contact with the species by community members in the Tembe River area, due to the higher concentration of *W. salutaris* there. Similar findings were reported in the northern Ukraine for *Viburnum opulus* L. due to its occurrence in nearby forests (Pieroni and Sõukand 2018).

Half of the respondents from TR were immigrants from other parts of the country. They nevertheless exhibited similar levels of knowledge of *W. salutaris* as indigenous people. LEK of nonindigenous people was likely acquired by transmission during social interaction with indigenous neighbors and friends (Souto and Ticktin 2012), as has been similarly reported for Latino immigrants among Mexico's indigenous Mayas (Atran et al. 2002). Local ecological knowledge acquisition is a lifetime learning process, and older members are often more knowledgeable than younger people (Agbani et al. 2018; Quilan et al. 2016). In the case of *W. salutaris*, the similarity of LEK exhibited by indigenous and nonindigenous residents may well be a function of the high commercial value and overall cultural salience of this valuable tree species (Voeks 2018).

Local ecological knowledge can be a useful tool in the development of conservation and management strategies (Turvey et al. 2013). In Madagascar, for example, local people provided reliable information on wildlife harvesting patterns, suggesting that LEK can contribute to the species monitoring process (Jones et al. 2008). In Mexico, Hellier et al. (1999) reported the decline of useful plants due to overharvesting and proposed the value of traditional knowledge in monitoring trends in local biodiversity. Thus, understanding of the depth and diversity of LEK, such as the information provided by respondents in this study, can offer valuable and necessary recommendations for conservation and management of overused species (Ghimire et al. 2004; Turvey et al. 2013).

Use Variation According to Area, Gender, and Age

The results revealed that knowledge differed significantly between the Tembe River and the Futi Corridor, as well as between men and women in these areas. This may be due to the long distances from their homesteads to *W. salutaris* collection grounds in the Futi Corridor and the Lebombo Mountains areas. In addition to being time-contingent, as noted earlier, ethnobotanical knowledge is also space-contingent, and close proximity of forests to homesteads facilitates greater opportunities for interaction between people and plants (cf. Byg and Balslev 2001). These results are supported by the application of optimal foraging theory in ethnobotany, which suggests that increasingly rare or distant plant resources will be used less than near and abundant resources (Gaoue et al. 2017) if for generalist uses.

In the case of southern Mozambique, large parts of the population migrated to South Africa and Swaziland during the civil war and stayed for many years, where they had improved access to modern medical facilities. In other cases, lack of employment opportunities in the study area prompted labor migration to regional urban areas, where they similarly had improved access to biomedicine. Access to modern medicine has been widely reported to undermine people's use and knowledge of medicinal plant species (Voeks 2018, pp. 237–238). In Oaxaca, Mexico, for example, knowledge and use of medicinal plants persists, but it has declined in importance with increasing access to modern medicine (Pérez-Nicolás et al. 2017).

Gendered divisions of knowledge of medicinal plant species are common in traditional societies, particularly where there are strong divisions of labor and space (Voeks 2018, pp. 171–177). In southwest Ethiopia, for example, where most medicinal plants come from home gardens, women are more knowledgeable than men because they work in the home gardens (Hunde et al. 2015). Similarly in Brazil, where most medicinal species are associated with anthropogenic habitats, women know the medicinal properties of more plant species than men (Voeks 2007). This is not universally the case, however. In South Africa, for instance, men are reported to be more knowledgeable about medicinal species than women (Dovie et al. 2008). However, contrary to these opposing patterns, our results indicated relatively few gender or age differences. This may be a consequence of the multidirectional and efficacy of knowledge transmission among community members (Lozada et al. 2006). Almost all the people in the study areas, young and old, male and female, nonindigenous and indigenous, used *W. salutaris*. This suggests that information on the species is widespread and acquired though vertical knowledge transmission from parents and grandparents along with horizontal transmission from neighbors or friends (Mathez-Stiefel and Vanderbroek 2012).

Implications for the Sustainable Use of *Warburgia*

Most households in the study areas relied on agriculture and NTFP collection for the bulk of their cash and noncash income (GDM 2008; INE, 2013a, b). This is a result of the limited job opportunities in the area, long distances to urban centers, and the generally low levels of formal education. *W. salutaris* is a key NTFP within local livelihoods, supporting the health of most households as well as providing cash incomes for some through their involvement in trading *W. salutaris* bark locally and farther afield (Veeman et al. 2014b). However, trade has been identified as the main cause of decline of this species in many parts of southern Africa due to high demand (cf. Botha et al. 2004; Krog et al. 2006). We believe that *W. salutaris* is at this time sustainably exploited in some parts of the study area, but that during the civil war, this was likely not the case. To ensure that the species is sustainably exploited into the future, considerations should be given to activities that encourage conservation and contribute to people's livelihoods. As suggested by Berkes (2004), access to natural resources is of utmost importance to the livelihoods of people living in natural environments, and any action that impedes access is likely to be disapproved by the local communities (Berkes 2004). Therefore, we propose that the limited number of existing *W. salutaris* traders in the three areas should be permitted to continue harvesting bark, with assistance and supervision provided by relevant resources agencies. Limiting the overall wild harvest of the species and at the same time encouraging its cultivation would benefit the local communities economically and contribute to conservation of the species. However, the viability of this small enterprise would require institutional support, as has been demonstrated elsewhere (Tewari 2012). For example, a NTFP enterprise established for production and commercialization of wild honey was created to respond to people's needs and to support forest conservation in Ethiopia. Through assistance from the Netherland Development Organization, Ethiopia is exporting wild honey to the European community (Lowore et al. 2018).

To promote early detection of unsustainable uses of *W. salutaris* in the study area, the regular inventory of the populations is essential. Additionally, determination of the rates of bark recovery in relation to plant, site, and harvesting approaches would be useful in contributing to local management guidelines (Botha et al. 2004; Delvaux et al. 2010). Monitoring of population trends can be done using simple methods such as size class profiles that will inform changes in mortality and recruitment rates (Cunningham 2001; Venter and Witkowski 2010). These studies could be integrated into the management plan of the species.

Conclusion

This study examined the uses, knowledge distribution, management practices, and LEK of the pepper-bark tree (*Warburgia salutaris*) in southern Mozambique. The species is employed to treat 12 health complaints and is mainly used for coughs, mouth, and throat sores. Gender and age did not influence knowledge and use of the species, suggesting that acquisition occurs through vertical and horizontal transmission from kin and neighbors. Bark is the most used part of the plant, but the leaves are also used to address a number of common ailments. Although less often used by respondents, leaf use could support *W. salutaris* conservation through substitution for bark. Furthermore, a considerable number of substitute species for *W. salutaris* were reported, and these could be used in lieu of *W. salutaris*. There are no reported prohibitions relating to *W. salutaris* harvest in the study areas, but there are some collection restrictions in the Futi Corridor, a formal protected area linked to the Maputo Special Reserve.

Outside of the Futi Corridor, very few respondents admitted to involvement in the bark trade, now or in the past. Similarly, confirmation of non-community members coming to collect *W. salutaris* was mostly reported for the Futi Corridor. Nevertheless, given the large quantities of *W. salutaris* bark of Mozambican provenance that has been and is flowing into nearby countries, it is most likely that (1) informants were or are involved in the bark trade and did not want to implicate themselves, (2) informants were or are not involved in trade but knew who commercial harvesters were and avoided implication of others, or (3) the longer distances to collection grounds in the Futi Corridor and possibly Lebombo Mountains favored commercial harvesting of the species. Some trade clearly still persists in southern Mozambique, but to ascertain which areas are involved, harvest impact and size class profile studies are needed.

Local management practices for *W. salutaris* are mainly through bark harvesting procedures, but avoiding wildfires, on-farm conservation, and cultivation were also mentioned. Cultivation of *W. salutaris* to create alternative sources of plant material has been recommended in the region as a primary tool for management of the species (Botha et al. 2004; Maroyi 2012; Veeman et al. 2014b), which would require regional collaboration. Long-term studies of post-harvest bark recovery are also necessary in order to recommend sustainable bark harvesting techniques for *W. salutaris*.

Finally, variation of habitat characteristics for *W. salutaris* in southern Mozambique revealed through LEK could inform possible reintroduction programs. Likewise, the ways that local people see the population trends in different periods will assist monitoring programs. Local people's views of the driving forces causing any decline in of *W. salutaris* should be integrated into the management plan of the species. The results of the present study could contribute to the design of an appropriate and locally sensitive conservation strategy for this important medicinal species in southern Mozambique.

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Compliance with Ethical Standards

Authorization for the research was granted by traditional and local leaders, as well as ethics approval by the departmental committee at Rhodes University (November 2015).

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