Hum Ecol
DOI 10.1007/s10745-016-9855-4

Responses to Malaria Incidence in the Sango Bay Forest Reserve, Uganda

Charles Galabuzi[1] · Goretie Nsubuga Nabanoga[1] · Paul Ssegawa[2] · Joseph Obua[1] · Gerald Eilu[1]

Abstract Globally up to two billion people live without or with limited access to effective malaria treatment. We studied a malaria-vulnerable forest community in Uganda to assess the harvesting protocols of plants used to treat malaria in order to determine their utilization thresholds. Up to 232 people were involved in interviews, focus group discussions, and forest transects walks during data collection. Data were analyzed qualitatively and quantitatively using SPSS 10.0 and MINITAB 12.0. Out of the 52 anti-malarial plants recorded, a total of 29 species were new to treating malaria in this region. Herbalists living furthest from the forest were of particular concern because they collected higher quantities than those closer. Men and women collected different plant species ($Z = 5.36$, $P < 0.001$) and the distances travelled by collectors ($Z = 4.542$, $P < 0.001$) affected the amounts gathered per visit. In the event of scarcity of plants for treatment, forest communities explore new alternatives. Retraining herbalists in less destructive harvesting procedures could reduce pressure on target species without restricting utilization.

Keywords Uganda · Harvesting protocols · Traditional medicine · Medicinal plants · Sango Bay Forest Reserve

✉ Charles Galabuzi
charlesgalabuzi@gmail.com

1 College of Agricultural and Environmental Sciences, P.O. Box 7062, Makerere University, Kampala, Uganda

2 College of Natural Sciences, P.O. Box 7062, Makerere University, Kampala, Uganda

Introduction

The potential of natural plants to provide medicine to humans is well documented (Cai *et al*. 2004; Duarte *et al*. 2005; Shokeen *et al*. 2005) and close to 90% of rural people's health care is sustained by almost exclusive reliance on native medicinal plants (Cunningham 1993; Sawsan and Al-Eisawi 2014). The search for potent medicinal plants continues to attract the attention of researchers worldwide (Gan *et al*. 2010; Silva *et al*. 2014; Van Andel *et al*. 2014) because they produce chemicals that are biologically active within themselves and in other living organisms (Adia *et al*. 2014; USDA 2014). Fruits and leaves generally have the most abundant quantities of chemicals (Duthie *et al*. 2000) and are consequently the most used plant parts to treat ailments (Sawsan and Al-Eisawi 2014). Up to 25% of drugs used in the international pharmacopeia are plant-derived and many others are synthetic analogs built on lead structure compounds isolated from plants (WHO 2002).

Ethno-botanical studies describe the selection of plants by humans by elaborating pharmacopeias and identifying species with the greatest potential for 'bio-prospecting' (Silva *et al*. 2014). These studies make extensive use of local knowledge to provide guidelines for discovering new active substances (Ahmed *et al*. 2014; Silva *et al*. 2014). Determining the utilization thresholds of medicinal plants, particularly of the vulnerable and threatened species (*Prunus africana* (Hook. F.) Kalkman (Cunningham *et al.* 1997) and *Warburgia ugandensis* Sprague is, however, still a challenge because it requires understanding the socio-economic needs of the users (IUCN 2013; Galabuzi *et al.* 2015). Strategies are urgently needed to formulate harvesting protocols for medicinal plants in order to establish utilization thresholds of plants whose conservation status is of global concern.

Published online: 19 October 2016

Although a number of studies have emphasized the contribution of native forest medicinal plants towards treating locally common ailments (Atindehou *et al*. 2002; Salvat *et al*. 2004; Duarte *et al*. 2005; Muthu *et al*. 2006; Coelho-Ferreira 2009; Rajeh *et al*. 2010), only a few have specifically listed plants used to treat malaria (Kakudidi *et al*. 2000; Andrade-Neto *et al*. 2008; Coelho-Ferreira 2009; Adia *et al*. 2014). Most of these studies fail to address safe ways of collecting medicinal plants especially from the wild. Yet unregulated methods of harvesting, such as ring barking and uprooting medicinal plants, in most cases kills the plant, affects natural regeneration and the plant population in the long term (Censkowsky *et al*. 2007; Galabuzi *et al*. 2015). Identification of new plants for malaria treatment in the tropics is especially topical since malaria is currently one of the most widespread health threats worldwide (Maregesi *et al*. 2010). However, such efforts should be accompanied with strategies for sustainability.

Within the past 10–15 years, medical studies have acknowledged the contribution of native plants to the evolution of new drug resistant malaria parasites (WHO 2002; Vastergaard and Ringwald 2007; NIH 2011). For example, the efficacy of drugs such as artemesinin, derived from *Artemesia annua* L., against multi-drug resistant malaria parasites cannot be overlooked (WHO 2002; Muthe *et al*. 2011). Unfortunately, the potential of some medicinal plants for effective treatment has escalated exploitation. Currently, up to two billion people live without or with limited access to effective treatment (Tilley *et al*. 2006), making documentation of new anti-malarial medicinal plants timely. We anticipate that within the next two decades the new lists will provide more alternatives to malaria-vulnerable communities in the tropics and perhaps reduce harvesting pressure on already exploited species.

Malaria kills more than one million people annually worldwide, 90 % of them in tropical developing countries, comprising of 70 % children under the age of five years (WHO 2007). According to the World Health Organization (WHO), Africa bears the highest burden of malaria with 80 % of the estimated 203 million cases and 90 % of the estimated 627,000 malaria deaths worldwide occurring in this region. By 2005 over 80 % of malaria deaths occurred in African countries south of the Sahara (WHO 2005). In 2012 alone, 77 % of all malaria deaths involved children under the age of five years. Every year, malaria costs Africa over USD12 billion and slows economic growth by 1.3 % (Molavi 2003). Robust strategies are required to reduce malaria incidence in areas where modern drugs are inadequate or absent (Adongo *et al*. 2005).

In the Sango Bay area of Uganda, the forest that is the main source of plants for treatment (Galabuzi *et al*. 2015) is at the same time a breeding site for malaria-carrying mosquitoes. The forest generally floods for most of the year creating favorable mosquito breeding areas, making malaria prevention difficult because of the risk of environmental damage. Current natural resource management protocols in the tropics are inadequate or non-existent on random and exploitive use of medicinal plants (Censkowsky *et al*. 2007; Galabuzi *et al*. 2015). Innovations need to be guided by research to be widely useful.

Here we report on ‘new’ plants used by one forest community in the Sango Bay area to treat malaria and demonstrate the importance of the socio-economic characteristics of the plant users in predicting harvesting patterns. Malaria disproportionately affects poor people, with almost 60% of cases occurring among the poorest 20% of the world’s population (WHO 2006). Resource-limited communities are at increased risk of both becoming infected with malaria and getting infected more frequently (Adia *et al*. 2014). We further analyse different preferences in harvesting practices between male and female herbalists, and whether the distances travelled by collectors to the forest influence harvesting protocols. We argue that this research provides data required for identifying utilization thresholds that could promote conservation of medicinal plant resources, as well as assisting rural communities in the tropics to reduce malaria prevalence.

Study Area

The study was conducted in the Sango Bay Forest Reserve (SBFR) (0° 47′ to 1° 00′ S and 31°28′ to 31°43′ E) located on the shores of Lake Victoria in southern Uganda (Fig. 1) (Uganda Department of Lands and Survey map sheets 88/iii (series Y732 at 1:50,000); Howard and Davenport 1996). The SBFR is on flat terrain (the Kagera flood plain) with an average elevation of 1160 masl. The area has two wet seasons (March-May and September-November), with average annual rainfall of 1,250 - 2,125 mm. Average annual temperatures range between 16 and 26°C and the relative humidity is high (80 - 90% in the morning and 61 - 66% in the afternoon).

The SBFR is one of the largest forest-wetland ecosystems in Uganda (Langdale-Brown *et al.* 1964). The forest vegetation covers about 192 km^2, approximately 31 % of the total SBFR. The remaining 69% of the reserve is predominantly grassland. The reserve is divided into five blocks: i) Kaiso (19 km^2); ii) Malabigambo (111 km^2); iii) Tero west (27 km^2); iv) Tero east (11 km^2); and v) Namalala (24 km^2). The study villages, Kanabulemu and Minziro, are within 5 km of the forest and where extensive use of forest plants to treat malaria and other local illnesses have been recorded (Ssegawa 2006).

The forest reserve was classified as *Baikiaea-Podocarpus* seasonal swamp (Langdale-Brown *et al*. 1964), and currently as secondary forest (Ssegawa and Kasenene, 2007a, b). Although species composition was impacted by logging for over 80 years (Howard and Davenport 1996) and harvesting of non-timber forest products (NTFP) (Ssegawa and Kasenene 2007a), the forests are biologically diverse with over 15% of Uganda’s flora (Ssegawa and Kasenene 2007b). The highly valued *Podocarpus* spp. harvested for timber was

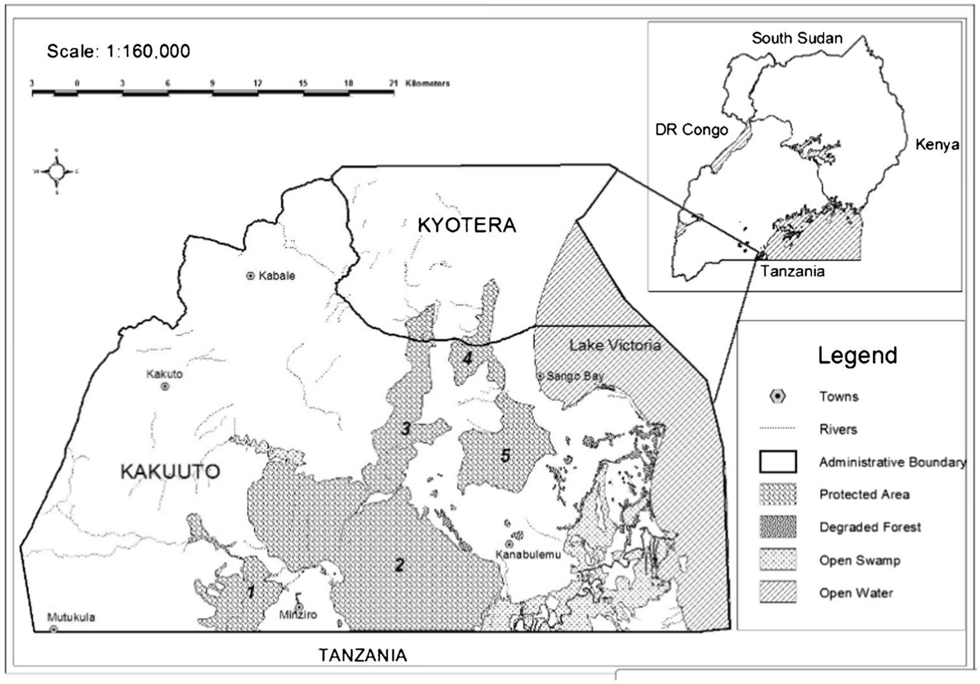

Fig. 1 Location of Sango Bay Forest Reserve blocks; 1) Kaiso, 2) Malabiambo, 3) Tero west, 4) Tero east and 5) Namalala. Data source: National Forestry Authority (NFA) GIS Unit, Kampala, 2014

most affected, including trunks of ≤ 10 cm Diameter at Breast Height (DBH). Currently, indications of harvesting tree bark likely for medicinal use, are common.

The forest reserve is an 'Important Bird Area,' and of biogeographic interest because it lies in the transition between the East and West African vegetation zones (Galabuzi *et al.* 2015). It is also a Ramsar[1] site, harboring species of global conservation concern. The forest has 317 species of birds, 236 species of trees and shrubs, 192 species of butterflies and 46 species of moths. Two plant species, *Euphorbia grantii, Heisteria parvifolia*, are found only in this forest, and a third, *Pseudagroststachys ugandensis,* is found also only in the Democratic Republic of Congo (Howard and Davenport 1996).

A local human population of about 500,000 people surrounds the reserve comprising 10 ethnic groups. The Baganda are the most numerous (about 65%); other groups include the Banyarwanda, Baziba, Banyambo and Barundi. The Baganda, Banyambo and Baziba practice mainly subsistence agriculture, cultivating maize (*Zea mays* L.), beans (*Phaseolus vulgaris* L.), groundnuts (*Arachis hypogaea* L.), sweet potatoes (*Ipomea batatus* L.), and cassava (*Manihot esculenta* Grantz), while the Banyarwanda and Barundi mainly keep cattle, mostly within the reserve (Galabuzi *et al.* 2015).

NTFPs, including medicinal plant materials (tree bark, leaves, roots, twigs) are regularly collected from the forest. On average, between five and eight people from villages both within five km from the forest and from more distant communities (Mutukula, Kyotera and Masaka) collect plant materials every day. Harvesting of medicinal plants and other NTFPs in Uganda's Forest Reserves is regulated by the National Forestry Authority (NFA). In some Protected Areas (PAs), management is in collaboration with local communities under the Collaborative Forest Management (CFM) agreement. The SBFR is among the PAs in Uganda where CFM was piloted. Under the CFM system, the NFA established local forest groups to encourage local interest in participatory forest management. However, since it failed to share the benefits of forest management with the local communities, interest in participatory management has disappeared (Galabuzi *et al.*, 2014). Consequently, illegal activities have continued in the forest. Moreover, inadequate government funding for the health and forestry sectors undermines control of illegal activities, and thus local people exploit available alternatives, including the forest plants for medicinal properties.

There is a higher incidence of malaria (at least one person in every five households) in SBFR communities compared to the rest of the country. Low birth weights, chronic anemia, and in some cases severe neurological complications are associated with malaria, compelling residents to continuously seek alternative treatments.

Methods

A total of 232 people volunteered to participate in our survey. These included 86 in semi-structured interviews, 120 in focus group discussions, and 26 in open guided interviews. Consent

[1] This refers to the international treaty on wetlands signed in the city of Ramsar, Iran, in 1971. As of March 2016 it protected 2231 sites.

from all participants was formally established through meetings organized by local leaders and the NFA. Up to 86 households were randomly selected in eight purposively selected forest villages. Villages adjacent to the forest were prioritized in light of the incidence of malaria and related disease reports from 2003 to 2007 (Whitworth *et al.* 2000; Tabuti *et al.* 2003; UGANEB 2005; Mbonye *et al.* 2006). In some of the study households in these villages, there are several signs of the collection or processing of medicinal plant materials. In every randomly selected household, at least one member took part in a semi-structured interview, usually the household head (female or male). In the aftermath of the HIV- Aids epidemic of the early 1980s through the late 1990s, some households in the study area are headed by females and others by young people between 15-20 years (Ssewankambo *et al.* 1994). Respondents included herbalists, and traditional birth attendants (TBAs). We recorded data on respondents' socio-economic status, plants they used to treat malaria, and their harvesting practices.

In addition, eight focus group discussions (of 10 to 15 participants) were used to verify the information gathered from individual household interviews and rank the identified anti-malarial plant species in order of potency. Key informants including traditional medicine (TM) practitioners were involved in transect walks in the forest and surrounding bush or grassland to locate and collect voucher specimens of the listed plants. The specimens were taken to Makerere University Herbarium (MHU) for identification.

We visited markets for medicinal plant products in the neighboring towns of Rakai, Masaka, Kasensero, Kyotera, and Mutukula and conducted open interviews with 26 medicinal plant traders in 10 permanent and four seasonal markets. Traders involved in processed and unprocessed anti-malarial products were interviewed. Formal markets are legally located for trading general merchandise including herbal remedies, while seasonal markets arise opportunistically either in rural communities or neighboring towns. The interviews elicited information on socio-economic status, experience with medicinal plant collection, product handling and quantities of plant raw materials required to produce specified quantities of the products sold. The quantities were estimated using relatively dry materials, not necessarily of the targeted anti-malaria species, found in the market.

Data Analysis

Data from focus group discussions and key informant interviews in the markets as well as structured field observations were analyzed qualitatively while data from individual household interviews were summarized and statistically analyzed in SPSS version 10.0 and MINTAB version 12.0.

Qualitative data were analyzed collectively with the participants using social methods such as pair-wise and wealth and preference ranking (Miles and Michael 1999). A list of anti-malarial plants generated during focus group discussions and individual interviews was compared with previous lists (Ssegawa and Kasenene 2007a, b). The plant lists were summarized based on family, genus, species, life forms, method and frequency of harvesting, and processing protocols.

Quantitative data were subjected to cluster analysis to establish similarities between male and female medicinal plant users (Hoft *et al.* 1999) in MINITAB. Distance from the forest, education and quantities of the anti-malarial plant material harvested were also used in cluster analysis to identify similarities in quantities collected in relation to education levels and distance travelled. We used the hierarchical agglomerative procedure based on unweighted and pair-group arithmetic averages (UPGMA) (Hoft *et al.* 1999; Eilu *et al.* 2003). In SPSS we used analysis of variance by ranks (Kruskal-Wallis H and Wilcoxon signed Rank Z tests) to establish relationships between socio-economic status (gender, income level, education, distance travelled, and age) of the respondents and quantities of anti-malarial plant material harvested (Eilu and Bukenya-Ziraba 2004).

Results

Socio-Economic Characteristics of Medicinal Plant Users

In the household survey of 86 respondents, 53 % were male and 47 % female. In the focus group discussion, 51 % were female and 49 % male, while in the market survey 80 % were female and only 20 % were male. An almost equal number of male and female participants are involved in the use of herbal products although the trade of medicinal plant remedies is dominated by the women. Less than one third of all participants in the study (26 %) were aged between 36 and 45 years, 51 % were also subsistence farmers, while 46 % earned about UGX 200,000 (approximately US $72[2]) annually and 75 % had only primary level education (Table 1). The use of anti-malarial medicinal plants is generally dominated by the relatively less educated as well as the elderly (>45 years), but its sale is not regarded as a major source of income.

New Plants Used for Malaria Treatment

We recorded a total of 52 anti-malarial plant species belonging to 29 families and 46 genera. The species belong to five life forms including 14 trees, 17 shrubs, 7 vines, 12 herbs (species) and one grass. The families Asteraceae and Fabaceae are the most represented with seven species each. A total of 29 species are new to malaria treatment from this

[2] One US$ = 2800 Uganda Shillings as of August 2009

Table 1 Socio-economic characteristics of the respondents from the household survey in Sango Bay area ($N = 86$)

Variable	Percentage (%)
Gender	
Male	53
Female	47
Age class (Years)	
15–25	5
26–35	17
36–45	26
46–55	24
56–65	12
66–75	13
≥ 75	2
Occupation	
Subsistence farmers	51
Commercial farmers	7
Herbalists	31
TBAs	3
Civil servants	8
Education attained	
No formal education	17
Primary	75
Secondary	5
Tertiary	3
Annual household income (Ug.shs)	
< 200,000 (US$ 71.4)	46
200,000–300,000 (US$ 71–107.1)	33
300,000–400,000 (US$ 107–142.8)	12
≥ 400,000 (≥ US$ 142.8)	9

[1] *USD = 2800 as per August 2009, TBA > Traditional Birth Attendant*

area. The five most important anti-malaria plants encountered are *Fleroya rubrostipulata* (K. Schum.) Y.F. Deng, *Zanthoxylum chalybeum* Engl., *Warburgia ugandensis* Sprague, *Alchornea cordifolia* Muell. Arg. and *Syzygium guineense* (Willd.) DC. (Table 2). The nature and number of plants used by people living with persistent ailments may vary with time across communities.

Harvesting Protocols of Anti-Malarial Plants

Local guidelines (i.e., taboos, beliefs) exist regarding collecting medicinal plant materials. A herbalist is, for example, required to harvest roots from a particular location, such as the direction of the sunset. In other cases, the herbalist has to collect plant parts during particular times of a day or month. Collection of some medicinal plants by women is restricted at certain times, e.g., during pregnancy, after giving birth, or during menstruation. No scientific explanation was given for these practices.

Ten anti-malarial trees are harvested mostly by debarking. These species include *F. rubrostipulata, W. ugandensis, S. guineense, Entada abyssinica* A. Rich *Maytenus senegalensis* (Lam.) Exell, *Parinari curatellifolia* Plauch, *and Psorospermum febrifugum* Spach. var *febrifugum*, *Shirakiopsis elliptica* (Hochst.) H.-J. Esser, *Syzygium cordatum* Krauss and *Albizia coriaria* Oliv. In some cases the entire trunks, particularly of *F. rubrostipulata* and *W. ugandensis,* are debarked up to the branches (i.e., about 10 meters from the base), while shrubs and herbs are harvested mainly by digging out the roots, plucking off leaves, or uprooting the whole plant.

The quantity of plant materials harvested at a time varies among collectors (Table 3). In the use of tree species, the bark is harvested most (about 10-40 kg) and for shrubs leaves and/twigs (about 5- 20 kg) are harvested. Nearly half of respondents harvested at least 8 -10 kg of bark per visit while 23% collected (20 -80 kg) of leaves, roots and bark. Only 19% of herbalists collected 5-10 pieces of bark from trees and 5% picked 5-20 leaves of herbs or shrubs such as *Rumex usamberensis* (Dammer) Dammer, *Rhus vulgaris* Meikle and *Psorospermum febrifugum*. Generally, bark harvesting is more common and destructive to the forest.

The quantities harvested by female and male herbalists were not significantly different ($H = 1.81$, $DF = 1$, $P = 0.178$, Kruskal-Wallis test). However, some female herbalists collected relatively larger quantities than male herbalists (Fig. 2). Female medicinal plant collectors target different species than male herbalists ($Z= 5.36$, $P< 0.001$, Wilcoxon signed Rank test). Out of the four most targeted anti-malarial tree species from the forest, *F. rubrostipulata* is the most preferred. The distances travelled by herbalists to the forest significantly influenced ($Z= 4.542$, $P<0.001$, Wilcoxon signed Rank test) the amounts collected on each visit (Fig. 3).

Age and education level are not important in determining the quantities of anti-malarial plant material collected. As expected, the herbalists living closest to the forest collect smaller quantities of medicinal plant materials, but more frequently than those living farther away (Table 3). The quantities collected by different age groups are not significantly different ($H = 3.53$, $DF = 6$, $P = 0.74$, Kruskal-Wallis test). Herbalists with different levels of education collect similar quantities of medicinal plant materials ($H = 1.96$, $DF = 3$, $P = 0.58$ Kruskal-Wallis test) and do not influence the patterns of harvesting.

Discussion and Conclusion

Socio-Economic Attributes of Medicinal Plant Users

While Adia *et al.* (2014) recorded more female healers compared to males, our survey recorded an almost equal number of women and men involved in traditional medical practices.

Table 2 A list of anti-malarial plants showing species in earlier studies, life forms and species recorded for the first time in the Sango Bay area

Botanic name	Family	Life form
Acalypha villicaulis A. Rich*	Euphorbiaceae	Herb
Albizia coriaria Oliv. **	Fabaceae	Tree
Alchornea cordifolia Muell. Arg.**	Euphorbiaceae	Shrub
Aloe volkensii Engl.*	Aloeaceae	Shrub
Aspilia africana (Pers.) C. D. Adams*	Asteraceae	Herb
Azadrichta indica A. Juss.*	Meliaceae	Tree
Bidens grantii (Oliv.) Sherft**	Asteraceae	Herb
*Bidens pilosa L.***	Asteraceae	Herb
Bridelia micrantha (Hochst.) Baill*	Euphorbiaceae	Shrub
Brillantaisia cacafricosic Lindau*	Acanthaceae	Vine
Cynodon ethiopicus Clayton &Harlan *	Poaceae	Grass
Cyphostemma adenocaule (A. Rich.) Willd. Drummond **	Vitaceae	Herb
Dracaena fragrans (L.) Ker- Gawl*	Dracaenaceae	Shrub
Dracaena steudneri Engl.*	Dracaenaceae	Tree
Entada abyssinica A. Rich	Fabaceae	Shrub
Eriosema psoraleoides (Lam.) G. Don*	Fabaceae	Vine
Erythrina abyssinica DC. **	Fabaceae	Tree
Flemingia grahamiana Wight e Arn.*	Fabaceae	Vine
Flueggea virosa (Willd.) Voigt*	Euphorbiaceae	Shrub
Fleroya rubrostipulata (K. Schum.) Y.F. Deng	Rubiaceae	Tree
Hibiscus fuseus Garck*	Malvaceae	Shrub
Hoslundia opposita Vache**	Lamiaceae	Shrub
Indigofera congesta Bak.f	Fabaceae	Herb
Justicia betonica L.*	Acanthaceae	Herb
Kotschya africana Endl. VarAfricana**	Fabaceae	Vine
Lasiodiscus mildbraedii Engl.*	Rhamnaceae	Tree
Maesa lanceolata Forssk.*	Mysinaceae	Shrub
Markhamia lutea K. Schum.	Bignonaceae	Tree
Maytenus senegalensis (Lam.) Exell*	Celestraceae	Shrub
Microglossa pyrifolia (Lam.) O. Ktze*	Asteraceae	Vine
Moringa oleifera Lam.*	Moringaceae	Tree
Ocimum lamifolium Benth.	Lamiaceae	Vine
Parinari curatellifolia Plauch	Chrysobalanceae	Shrub
Piper umbellatum L.*	Piperaceae	Herb
Plectranthus prostratus Giirke *	Lamiaceae	Herb
Pseudarthria hookeri Wight Arn.	Fabaceae	Vine
Psoropermum febrifugum Spach. Var febrifugum*	Guttifarae	Shrub
Rhus natalensis Krauss*	Anacardiaceae	Shrub
Rhus vulgaris Meikle*	Anacardiaceae	Vine
Rumex usamberensis (Dammer) Dammer*	Polygnoceae	Herb
Senecio petitianus A. Rich*	Asteraceae	Shrub
Shirakiopsis elliptica (Hochst.) H.-J. Esser	Euphorbiaceae	Tree
Sopubia ramosa Hochst.	Scrophulariaceae	Herb
Syzygium cordatum Krauss**	Myrtaceae	Tree
Syzygium guineense (Willd.) DC.	Myrtaceae	Tree
Triumfetta macrophylla K. Schum.*	Tiliaceae	Shrub
Uapaca guineense (Don.) Muell. Arg.*	Euphorbiaceae	Tree
Vernonia amygdalina Del.	Asteraceae	Shrub
Vernonia campanea S. Moore*	Asteraceae	Herb

Table 2 (continued)

Botanic name	Family	Life form
Vernonia lasiopus O. Hoftm.	Asteraceae	Vine
Warburgia ugandensis Sprague	Canellaceae	Tree
Zanthoxylum chalybeum Engl.	Rutaceae	Tree

* *Species recorded for the first time as anti-malarial plants in the Sango Bay area*

** *Anti- malaria species recorded for other medicinal purposes (Ssegawa and Kasenene 2007a, b) in the Sango Bay forests*

As also observed in other studies (Tabuti *et al*. 2003; Galabuzi 2008; Adia *et al*. 2014), most herbalists have limited formal education, suggesting that indigenous knowledge on medicinal plants is transmitted verbally. According to Towns *et al.* (2014), sale of medicinal plants makes substantial contributions to the income of healers as well as to the health of consumers; the majority of sub-Saharan African populations use medicinal plants to meet their health care needs. Our results differ. The average annual income of the people involved is likely to be higher than reported in the current survey because i) sale of medicinal plants is generally untaxed, ii) sales of some plants are difficult to trace probably because they are illegal, and iii) the value of herbal remedies varies in relation to the "expertise" of the practitioner, location (Schippmann *et al*. 2002) and demand for the products (Jusu and Sanchez 2013; Quiroz *et al*. 2014). In developing countries it is difficult to establish the actual income of people involved in the informal sector (Towns *et al*. 2014), which in Uganda is commonly viewed as dominated by the poor who are generally skeptical about the benefits of formalizing their business.

Anti-Malarial Plants Recorded

Compared to earlier studies in the SBFR (Ssegawa and Kasenene 2007a, b), we recorded a total of more 29 anti-malarial plant species, including nine species previously recorded for non anti-malarial medicinal purposes (Ssegawa and Kasenene 2007b). While informants prioritized *F. rubrostipulata, Z. chalybeum, W. ugandensis, V. amygdalina* and *S. guineense,* (Ssegawa and Kasenene 2007a), our survey also includes *A. cordifolia* among the top most potent anti-malarial plants in the area. *A. cordifolia* and *W. ugandensis* are reported to be among the most important anti-malarial medicinal plants in other traditional healer communities in Central Uganda (Adia *et al*. 2014; Galabuzi *et al*. 2015). Communities consistently use similar plants for treating local ailments, and periodically replace less potent species with new ones.

Our survey recorded similar plant families and genera to those reported for other places (Kakudidi *et al.* 2000; Owuor *et al*. 2006; Adia *et al*. 2014) and previous surveys (Kokwaro 1976; Tabuti *et al*. 2003; Dharani 2005; Kamatenesi-Mugisha *et al.* 2007; Katuura *et al.* 2007). For example, species such as *Azadrichta indica* have been promoted in several malaria control programs (Kayanja and Byarugaba 2001; Merlin and Bodekker 2004; Dharani 2005; Adia *et al*. 2014; Ahmed *et al*. 2014), while indigenous species such as *W. ugandensis* have been documented to control other local ailments such as gynecological morbidity in western Uganda (Kamatenesi-Mugisha *et al*. 2007). Shared knowledge perhaps leads to similarities in the use of medicinal plant resources within and across communities (Adia *et al*. 2014). The additional species we recorded can be attributed to differences in knowledge and experience or "expertise" about the uses of botanic resources among forest human communities.

Harvesting Protocols of Anti-Malaria Plants

Cunningham and Davis (1997) observed that debarking trees and digging out roots of shrubs are destructive. Our study found the harvesting of tree leaves to have a relatively low

Table 3 Harvesting practices in relation to gender and distance travelled to collect medicinal plant materials

Quantity harvested	(%)		Frequency	Distance (Km)				
	Female	*Male*		*<1*	*1–2*	*5–10*	*>10*	*Total*
8–10 Kg of bark	11	40	Daily	6	6	3	2	17
20–80 Kg leaves and bark	13	10	1–4 times a week	3	4	2	0	09
5–10 pieces of bark or leaves	16	3	1–4 times a month	9	14	4	4	31
5–20 leaves only	5	0	1–4 times a year	9	14	4	2	29
1–2 roots	2	0						
Total	47	53		27	38	13	8	86

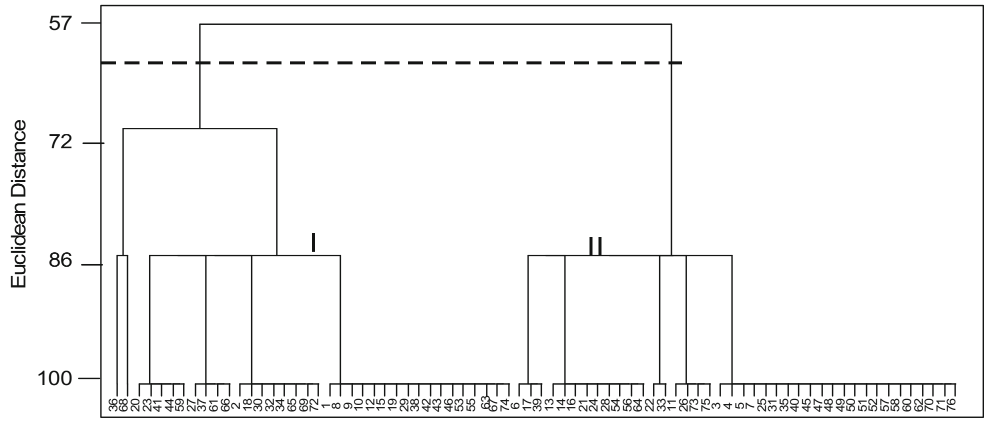

Fig. 2 Cluster of quantities harvested by herbalists with respect to gender. Cluster I represents female herbalists collecting 5–10 leaves and 8–20 kg of wet bark. Cluster II represents male herbalists collecting over 5 kg of leaves, 8–10 kg and 20–80 kg of bark

impact, suggesting that collecting leaves is the preferable way of utilizing a medicinal plant. However, collecting leaves in large amounts, especially during the dry season, can kill the tree. In the case of small and medium sized shrubs, uprooting the whole plant to remove its roots is not acceptable because it directly kills the plant (Cunningham *et al.* 2002). In addition, digging out 1-2 roots from larger trees or shrubs such as *Z. chalybeum*, may kill the tree over the long run (Mander *et al*. 1997; Duthie *et al*. 2000; Cunningham *et al.* 2002; Geldenhuys 2004).

Herbalists living close to the forest impact medicinal plants less often than those coming from farther away. With more forest monitoring groups involved under the CFM arrangement, herbalists traveling from distant areas possibly minimize the costs of acquiring the medicine by maximizing collection of the targeted species. The impact could even be higher if the targeted species is rare or its collection is legally prohibited (Cunningham *et al.* 2002). *F. rubrostipulata* was most preferred species by both men and women, probably because it is considered the most potent and can be easily administered. This has a direct impact on the species population by constraining management planning, and leads to inappropriate monitoring strategies for such plant resources (Galabuzi *et al.* 2015).

The collection of some plants by either women or men demonstrates that ethnobotanical knowledge can differ between men and women, likely related to specific health requirements, for example, during pregnancy. Furthermore, in most sub-Saharan African communities, women are at the centre of a household's welfare and in particular the care of children (Nabanoga 2005; Kamatenesi-Mugisha *et al.* 2007; Galabuzi 2008).

Local beliefs are important in guiding, regulating or promoting collection of herbal medicines (Ngqobe 1993; Dzerefos and Witkowski 2001). However, none of these beliefs are specifically attached to methods of harvesting targeted anti-malarial species in the SBFR. Prohibition of some plant collection by women during pregnancy, after birth, or during menstruation is probably an indirect way of regulating harvesting frequencies of special plant species used to reduce complications related to female fertility or the health of a new born, and thus ensuring sustainability. It is likely that traditional beliefs have more utility in dealing with psychological rather than physiological disorders (Adia *et al*. 2014).

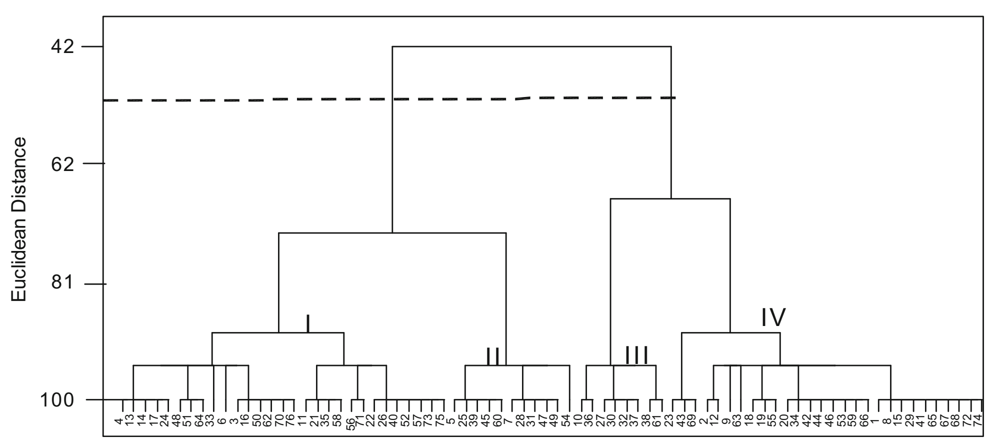

Fig. 3 Quantities collected by herbalists clustered with respect to distance travelled to the forest. Cluster I represents herbalists living within <1 km from the forest and collecting 5–10 leaves and 8–10 kg of wet bark. Clusters II represent herbalists living 5–10 km and harvesting 8–10 kg and 20–80 kg of wet bark, while III represent herbalists travelling 1–2 km to collect 8–10 kg and 20–80 kg of bark

Acknowledgments The Allachy medicinal plants grant of Plant life International funded this study through the Uganda Group of the African Network of Ethnobiology (UGANEB). We thank Alan Hamilton for visiting the field sites and offering useful advice. We thank the local people of Minziro and Kanabulemu for participating in this study.

References

Adia M. M., Anywar G., Byamukama R., Kamatenesi-Mugisha M., Sekagya Y., Kakudidi E. K., and Kiremire B. T. (2014). Medicinal plants used in malaria treatment by Prometra herbalists in Uganda. Journal of Ethnopharmacology 155: 580–588.

Adongo P. B., Kirkwood B., and Kendall C. (2005). How local community knowledge about malaria affects insecticide-treated net use in northern Ghana. Tropical Medicine and International Health 4: 366–378.

Ahmed N., Mahmood A., Tahir S. S., Bano A., Malik R. N., Hassan S., and Ashraf A. (2014). Ethnomedicinal knowledge and relative importance of indigenous medicinal plants of Cholistan desert, Punjab Province, Pakistan. Journal of Ethnopharmacology 155: 1263–1275.

Andrade-Neto V. F., Brandao M. G. L., Nogueira F., Rosa'rio V. E., and Krettli A. U. (2008). *Ampelozyziphus amazonicus* Ducke (Rhamnaceae), a medicinal plant used to prevent malaria in the Amazon region, hampers the development of plasmodium berghei sporozoites. International Journal for Parasitology 38: 1505–1511.

Atindehou K. K., Kone M., Terreux C., Traore D., Hosttettman K., and Dosso M. (2002). Evaluation of anti-microbial potential of medicinal plants from the Ivory Coast. Phytotherapy Research 24: 17–20.

Cai Y. Z., Luo Q., Sun M., and Corke H. (2004). Antioxidant activity and phenolic compounds of 112 traditional Chinese medicinal plants associated with anticancer. Life Science 74: 2157–2184.

Censkowsky U., Helberg U., Nowack A. and Steidle M (2007). Overview of 13 world production and marketing of organic wild collected products, ITC and IFOAM, 14 Geneva. Online 30th October 2013 10.55 GMT http://www.intracen.org/ www.ifoam.org.

Coelho-Ferreira M. (2009). Medicinal knowledge and plant utilization in an Amazonian coastal community of Marudá, Pará state (Brazil). Journal of Ethnopharmacology 126: 159–175.

Cunningham A.B. (1993). African medicinal plants: Setting priorities at the interface between conservation and primary health care. People and Plants Working Paper No. 1. UNESCO Paris.

Cunningham A. B., and Davis G. W. (1997). Human use of plants. In Cowling R. M., Richardson D. M., and Pierce S. M. (eds.), Vegetation of South Africa, University Press, Cambridge.

Cunningham M., Cunningham A. B., and Schippmann U. (1997). Trade in *Prunus africana* bark and the implementation of CITES, Bundenasmt for Naturschutz, Bonn.

Cunningham, A.B., Ayuk, E., Franzel, S., Duguma, B. and Asanga, A. (2002). An economic evaluation of medicinal tree cultivation, *Prunus africana* in Cameroon. People and plants working paper 10: UNESCO, Paris.

Dharani N. (2005). Field guide to common trees and shrubs of East Africa, Struik Publishers, Cape Town.

Duarte M. C., Figueria G. M., Sartoratto A., Rehder V. L., and Delarmelina C. (2005). Anti-Candida activity of Brazillian medicinal plants. Journal of Ethnopharmacology 97: 305–311.

Duthie G. G., Duthie S. J., and Kyle J. A. M. (2000). Plant polyphenols in cancer and heart disease: implications as nutritional antioxidants. Nutrition Research Reviews 13: 79–106.

Dzerefos C. M., and Witkowski E. T. F. (2001). Density and potential utilization of medicinal grassland plants from Abe bailey nature reserve, South Africa. Biodiversity and Conservation 10: 1875–1896.

Eilu G., and Bukenya-Ziraba R. (2004). Local use of climbing plants of Budongo Forest reserve, western Uganda. Journal of Ethnobiology 24(2): 307–327.

Eilu, G., Hafashimana, D.L.N. and Kasenene, J.M. (2003). Environmental factors and Floristic of some Albetine rift forests in Western Uganda. In the diversity and distribution of climbers and trellises in some forests of the Albetine rift, Western Uganda. Unpublished PhD thesis, Makerere University, Kampala.

Galabuzi C. (2008). Conservation, and local utilization of key anti-malarial medicinal plants in the Sango Bay area, Southern Uganda. Unpublished MSc, Thesis, Makerere University Kampala.

Galabuzi C., Eilu G., Mulugo L., Kakudidi E., Tabuti J. R. S., and Sibelet N. (2014). Strategies for empowering the local people to participate in forest restoration. Agroforestry Systems 88: 719–734. doi:10.1007/s10457-014-9713-6.

Galabuzi C., Eilu G., Nabanoga G. N., Ssegawa P., Obua J., Mulugo L., Kakudidi E., Tabuti J. R. S., and Sibelet N. (2015). Double jeopardy: bark harvest for malaria treatment and poor regeneration threaten tree population in a tropical forest of Uganda. African Journal of Ecology 53: 214–222. doi:10.1111/aje.12158.

Gan R., Kuang L., Xu X., Zhang Y., Xia E., Song F., and Li H. (2010). Screening of natural anti-oxidants from traditional Chinese medicinal plants associated with treatment of rheumatic disease. Molecules. doi:10.3390/molecules15095988.

Geldenhuys C. J. (2004). Bark harvesting for traditional medicine: from illegal resource degradation to participatory management. Scandinavian Journal of Forest Research 19(4): 103–115.

Hoft M., Barik S. K., and Lykke A. M. (1999). Quantitative ethnobotany: applications of multivariate and statistical analyses in ethnobotany. In People and plants working paper 6, UNESCO, Paris.

Howard P.C., Davenport T. (1996). Sango Bay Forest Reserves Biodiversity Report, No. 20, pp.107 Kampala.

IUCN (2013). IUCN Red list vulnerable species, On line 30th December 2013, 14.55 GMT http://en.wikipedia.org/wiki/Category:IUCN_Red_List_vulnerable_species.

Jusu A., and Sanchez A. (2013). Medicinal plant trade in Sierra Leone: threats and opportunities for conservation. Economic Botany 68: 16–29.

Kakudidi E. K. Z., Bukenya–Ziraba R., and Kasenene J. M. (2000). The medicin plants in and around Kibale national park, western Uganda. Norwegian Journal of Botany 5(4): 109–124.

Kamatenesi-Mugisha M., Oryem-Origa H., and Olwa-Odyek (2007). Medicinal plants used in some gynaecological morbidity ailments in western Uganda. African Journal of Ecology 45: 34–40.

Katuura E., Waako P., Ogwal-Okeng J., and Bukenya-Ziraba R. (2007). Traditional treatment of malaria in Mbarara district, western Uganda. African Journal of Ecology 45(1): 48–51.

Kayanja F. I. B., and Byarugaba D. (2001). Disappearing forests of Uganda: the way forward. Science in the third world. Current Science 81: 8–25.

Kokwaro J. O. (1976). Medicinal plants of East Africa, East African bureau, Nairobi, Kenya.

Langdale-Brown I., Osmaston A. H., and Wilson J. G. (1964). The vegetation of Uganda and its bearing on land use, Government printer, Entebbe Uganda.

Mander J., Quinn M. and Mander M. (1997). Trade in wildlife medicinal in South Africa. Insititute of Natural Resources Investigation Report No.154, INR, Pietermaritzburg.

Maregesi, S.,VanMiert, S., Pannecouque, C.M., Haddad, M.F.H., Hermans, N., Wright, C.W., Vlietinck, A.J.,A pers, S., Pieters, L., (2010). Screening of Tanzanian medicinal plants against plasmodium falciparum and human immune deficiency virus. Planta Medica 76: 195–201.

Mbonye A. K., Stella N., and Pascal M. (2006). Preventing malaria in pregnancy: a study of perceptions and policy implications in Mukono district, Uganda. Health Policy Planning 21(1): 17–26. doi:10.1093/heapol/czj002.

Merlin L. W., and Bodekker G. (2004). Traditional herbal medicines for malaria. British Medical Journal 329: 1156–1158.

Miles M. B., and Michael A. (1999). Qualitative data analysis, Second edn., Sage Publications, London.

Molavi A. (2003). Africa's malaria death toll still outrageously high, National Geographic news.nationalgeographic.com/news/2003/06/0612_030612_malaria retrieved on 10th Feb 2008

Muthe J. K., Gakuya D. W., Mbaria J. M., Kareru P. G., Mulei C. M., and Njonge F. K. (2011). Ethnobotanical study of anthelmintic and othermedicinal plants traditionally used in Loitoktok district of Kenya. Journal of Ethnopharmacology 135: 15–21.

Muthu C., Ayyanar M., Raja N., and Ignacimuthu S. (2006). Medicinal plants used by traditional healers in Kancheepuran district of Tumil Nadu. Indian Journal of Ethnobiology and Ethnomedicine 2(1): 43.

Nabanoga G. N. (2005). Transgressing boundaries: gendered spaces, species, and indigenous Forest Management in Uganda. In Tropical resource management papers 60 ISSN 0926–9495, Wageningen, Wageningen University.

Ngqobe Z. (1993). The roots of black conservation. New Ground 11: 12–15.

NIH (2011) Drugs from nature, then and now, In: Medicines by Design. Retrieved on 10th Feb 2013. http://publications.nigms.nih.gov/.

Owuor B. O., Kamoga D., Kungu J., and Njoroge G. N. (2006). Some medicinal trees and shrubs of eastern Africa for sustainable utilization and commercialization. ICRAF, Nairobi pp. 84.

Quiroz D., Towns A. M., Sènan I., Swier J., Brière S., Sosef M., and vanAndel T. (2014). Quantifying the domestic market in herbal medicine in Benin, West Africa. Journal of Ethnopharmacology 151: 1100–1108.

Rajeh M. A. B., Zuraini Z., Sasidharan S., Latha L. Y., and Amutha S. (2010). Assessment of *Euphorbia hirta* L, Leaf, Flower, Stem and Root Extracts for Their Antibacterial and Antifungal Activity and Brine Shrimp Lethality. Molecules. doi:10.3390/molecules15096008.

Salvat A., Antonacci L., Fortunato R. H., Suarez E. Y., and Godoy H. M. (2004). Anti-microbial activity in methanoic extracts of several species from northern Argentina. Phytomedicine 11: 230–234.

Sawsan A. O., and Al-Eisawi D. M. (2014). Medicinal plants in the height mountains of northern Jordan. International Journal of Biodiversity and Conservation 6(6): 436–443.

Schippmann, U., Leaman, D., Cunningham, A., (2002). Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues, biodiversity and the ecosystem approach in agriculture, forestry and fisheries: 12–13 October 2002. Inter-Departmental Working Group on Biological Diversity for Food and Agriculture, Rome.

Shokeen P., Ray K., Bala M., and Tandon V. (2005). Preliminary studies on activity on *Ocimum sanctum*, *Drynaria quecifolia* and *Annona squamosa* against *Neisseria gonorrhoeae*. Sexually Transmitted Diseases 32: 106–111.

Silva F. D., Albuquerque U. P., Júnior L. M. C., Lima A. D., Nascimento A. L. B., and Monteiro J. M. (2014). An ethnopharmacological assessment of the use of plants against parasitic diseases in humans and animals. Journal of Ethnopharmacology 155: 1332–1341.

Ssegawa, P. (2006). Plants for malaria in southern Uganda: local use, ecological viability and management. Unpublished PhD. Thesis, Makerere University Kampala.

Ssegawa P., and Kasenene J. M. (2007a). Plants for malaria treatment in southern Uganda: traditional use, preference and ecological viability. Journal of Ethnobiology 27(1): 110–131.

Ssegawa P., and Kasenene J. M. (2007b). Medicinal plant diversity and uses in the Sango Bay area, southern Uganda. Journal of Ethnopharmacology 113: 521–540.

Ssewankambo N. K., Wawer M. J., Gray R. H., Serwadda D., Li C., Stallings R. Y., Musgrave S. D., and Konde-Lule J. (1994). Demographic impact of HIV infection in rural Rakai District, Uganda: results of a population-based cohort study. Journal of the International Aids Society 8(12): 1639–1741.

Tabuti J. R. S., Lye L. A., and Dhillion S. S. (2003). Traditional herbal drugs of Bulamogi, Uganda: plants, use and administration. Journal of Ethnopharmacology 88: 19–44.

Tilley L., Davis T. M., and Bray P. G. (2006). Prospects for the treatment of drug-resistant malaria parasites. Future Microbiology 1: 127–141.

Towns A. M., Quiroz D., Guinee L., Boer H., and vanAndel T. (2014). Volume, value and floristic diversity of Gabon's medicinal plant markets. Journal of Ethnopharmacology 155: 1184–1193. doi:10.1016/j.jep.2014.06.052.

UGANEB (2005). Conservation and sustainable use of key malaria medicinal plants in South –central Uganda. *A proposal submitted to the Plantlife international- the wild plant conservation charity.* Plant conservation and livelihoods programme; Medicinal plant conservation initiative Salisbury Wiltshire.

USDA (United States Department of Agriculture) (2014). Active plant ingredients used for medicinal purposes. U.S. Forestry Service, Washington D.C. On line 9th September 2014 15.55 GMT http://www.fs.fed.us/wildflowers/ethnobotany/medicinal/ingredients.shtml

Van Andel T., de Boer H. J., Barnes J., and Vandebroek I. (2014). Medicinal plants used for menstrual disorders in Latin America, the Caribbean, sub-Saharan Africa, south and Southeast Asia and their uterine properties: a review. Journal of Ethnopharmacology 155: 992–1000.

Vastergaard L. S., and Ringwald P. (2007). Responding to the challenge of antimalarial drug resistance by routine monitoring to update national malaria treatment policies. American Journal of Tropical Medicine and Hygiene 77: 153–159.

Whitworth J., Morgan D., Quigley M., Smith A., Mayanja B., Eotu H., Omoding N., Okongo M., Malamba S., and Ojwiya A. (2000). EffectofHIV-1andincreasing immune-suppression on malaria parasitaemia and clinical episodes in adults in rural Uganda: a cohort study. The Lancet 356(9235): 1051–1056.

WHO (2002). Traditional and alternative medicine. Fact sheet No. 271.

WHO (2005). Malaria and HIV interactions and their implications for public health policy. In 20 Avenue Appia, Organization, World Health.

WHO (2006). The Africa malaria report 2006, Regional Offices for Africa and Eastern Mediterranean, World Health Organisation.

WHO (2007) Malaria: current global situation and trends. National malaria Control Programme, WHO/SEARO, http://www.searo.who.int/EN/Section10 htm retrieved on 9 Feb 2008.