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P u b l i s h e r s

Local knowledge and practices on use and management of edible insects in Lake Victoria basin, East Africa

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RESEARCH ARTICLE

Abstract

Edible insects (EIs) provide an important food source in Africa, but their potential to improve livelihoods and environmental conservation is yet to be fully exploited. This study contributes towards enhancing the use of EIs in the Lake Victoria basin (LVB), with particular attention to local perspectives of the catalogue, ecology, management, collection, processing and consumption. The study was conducted along the LVB in Uganda, Burundi and Rwanda between 2012 and 2013 using a household survey and focus group discussions. Results revealed that up to 20 insect species were eaten in Uganda, 13 in Burundi, and six in Rwanda. In Uganda, the most consumed insects were a katydid grasshopper (*Ruspolia differens*), palm weevil (*Rhynchophorus phoenicis*) larvae and termites (*Macrotermes*), while in Rwanda and Burundi, *Macrotermes* species were the most consumed. The most common source of EIs in households was their own collection from the wild, although a number of insects were also bought from markets. Local communities reported various ways of collecting, processing and storing insects. Overall, most of these activities require technological interventions. Despite the high consumption of EIs, no deliberate efforts were reported on conservation and rearing of any of the insects consumed in the three countries. This raises serious questions pertaining to the sustainable consumption of EIs, especially in the face of climate change in this region.

Keywords: climate change, developing countries, entomophagy, food security, local communities

1. Introduction

Entomophagy, consumption of insects as food, is gaining worldwide recognition. Edible insects (EIs) constitute a high quality food for humans, livestock, poultry and fish (Van Huis *et al.*, 2013). According to Van Huis (2013), insects have always been a part of human diet in many countries around the world, but predominantly in parts of Asia, Africa and Latin America. It is estimated that insects supplement the diet of some 2 billion people around the world (Van Huis *et al.*, 2013). Some 2,000 species of insects are eaten worldwide with an estimated 524 insect species consumed in Africa, 349 in Asia, 679 in the Americas, 152 in Australia, and 41 in Europe (Jongema, 2015). The most commonly consumed insect species belong to the order Coleoptera

followed by Lepidoptera, Hymenoptera, and Orthoptera, respectively (Jongema, 2015).

The need for alternative protein sources (other than 'meat' from livestock) is widespread and more so in the developing world (FAO, 2010; Paletti and Dreon, 2005). Edible insects are a good source of protein and they are considered to be environmentally friendly sources of protein (Rumpold and Schlüter, 2013). This is because insects produce much smaller quantities of greenhouse gases per kilogram of meat compared to conventional livestock (Klunder *et al.*, 2012; Oonincx *et al.*, 2010, 2012). Studies indicate that the protein and energy content of insects is comparable to that of conventional meat sources (Blásquez *et al.*, 2012; Chakravorty *et al.*, 2014). Therefore, the promotion of EIs

can provide a good and sustainable alternative protein source either for direct human consumption, or indirectly as animal feed.

The contribution of EIs to human diets has become even more important as food insecurity increases in developing countries and more people develop a taste for insects. Internationally, there is a greater call for development of the EIs industry (Rumpold and Schlüter, 2013; Van Huis, 2013). It is envisaged that the commercialisation and marketing of EIs could create money-making opportunities and add key nutrients to the diets of vulnerable populations. This is more so in the present circumstances where climate change is threatening agricultural production and an increase in food security in many parts of the world (Agea *et al.*, 2008).

Being a renewable resource, the exploitation of EIs by local communities is usually through their indigenous knowledge systems (IKS) in resource use practices and management systems. Local knowledge refers to a body of knowledge and insights possessed by local people about their immediate environment and the practices and beliefs that the people have adopted and evolved over time (Mbata *et al.*, 2002). Indigenous knowledge is used by the local communities to monitor and regulate natural resource use so as to ensure sustainable exploitation. As such IKS is a crucial factor in maintaining and promoting EIs (Paoletti and Dreon, 2005).

Some of the aspects of IKS critical for EIs relate to their conservation, collection and processing. Harvesting of EIs is reported to be done mainly by women and children, for whom insect farming can be a low-input sustainable form of agriculture (Van Huis, 2003). The method of collecting EIs is noted to be dependent on the insects' behaviour. For example, low temperatures in the morning make insects comparatively inactive and catching them is easy; nocturnal insects (such as termites and grasshoppers) can be caught using light traps as they are attracted to light; artificial breeding sites are useful for attracting palm weevils, whereas crickets and cicadas can be traced by the sound they make (Van Huis, 2003). According to Gahukar (2011), local people know which insects are edible as well as where and when to find them, and how to catch them. Such knowledge should be tapped into to guide the development of appropriate conservation, harvesting and processing methods.

Despite the fact that EIs provide an important food source for communities in Lake Victoria basin (LVB) (Ayieko, 2007; Kagezi *et al.*, 2010; Nyeko and Olubayo, 2005), there is a dearth of empirical data on IKS and practices on use of EIs in the region. According to Agea *et al.* (2008), the contribution of EIs to household food security and income in LVB has remained largely unknown. Very little is documented about IKS and local perceptions of management and utilisation of insects eaten by different societies in the region.

To promote insects as a potential food resource and as means of climate change adaptation, there is an urgent need to document the threatened IKS about insects as food for humans and to disseminate this knowledge to local communities (Kagezi *et al.*, 2010). Such information could be used to guide edible insect policy and product development. This study documented IKS, perceptions, preference and practices about EIs in the LVB. The key hypothesis was that local communities in LVB have well develop knowledge systems on EIs that can be used to develop technologies for their sustainable utilisation. Ultimately, such information will be useful in enhancing the use of EIs in the LVB for household food security and climate change adaptation.

2. Materials and methods

The study was conducted along the LVB in Uganda, Burundi and Rwanda. Data were collected from two districts in Burundi (Makamba and Gitega), three districts in each of Rwanda (Rubavu, Rusizi, and Kicukiro) and Uganda (Kalangala, Iganga and Masaka). Selection of the study districts was purposive, guided by knowledge on the distribution of known EIs and entomophagy obtained through literature review and key informants. The island district of Kalangala in Uganda and the island sector of Nkombo within Rusizi district in Rwanda were selected to generate information from geographically isolated local communities. Households were mainly engaged in small scale farming. Fishing was carried out in Kalangala and Masaka in Uganda and Rusizi in Rwanda.

A structured questionnaire and focus group discussions (FGDs) were used to collect data. Reconnaissance visits and baseline surveys were first conducted to assess the current situation, opportunities, local communities' understanding and interpretation of EIs, and threats for the execution of the planned study. Pre-testing of the questionnaire was done in one district in each country – Iganga in Uganda, Makamba in Burundi and Rubavu in Rwanda. Similarly, the harmonised checklist for FGDs was pre-tested by holding two meetings with local communities in one districts in each country. While the English version of the questionnaire was used in Uganda, a French version was used in Rwanda and Burundi for ease of administering. During the survey, household heads were interviewed with the help of research assistants who were recruited, trained and tested in administering the questionnaire during the pre-testing. Simple random sampling was used to select the survey participants.

The household survey questionnaire focused on household socio-demographic profiles, collection, uses, processing, storage, and conservation of EIs. A total of 60 households were surveyed in each of Iganga and Masaka districts in

Uganda, while 30 respondents were interviewed in each district in Burundi and Rwanda; giving a total sample size of 270 respondents. A larger sample size was used in Ugandan sites compared to those in Burundi and Rwanda because the latter are much smaller in size and less populated.

Focus group discussions were conducted in the same districts where household surveys took place. Overall, sixteen FGDs were held in the three countries (two in each study district). The number of local participants in each FGD ranged from six to 12 people. To ensure triangulation, each focus group discussion included women, men, youth and elders. The group discussions focused on basic ecology (habitats, temporal and spatial distribution of EIs in village landscapes and conservation practices) and methods of collection of EIs. Information was also sought on the communities' perception on the influence of climate change on availability of EIs and coping strategies. Additionally, direct field observations, quick inventories and open group meetings were conducted. Open group meetings focused on generating a list of edible insect species in the area, and where possible, members were asked to collect insect samples for further species identification which was done at Makerere University, Kampala, Uganda. The species were ranked through a priority ranking exercise.

Household survey data were coded, entered and analysed in the Statistical Package for Social Scientists (SPSS version 18.0, 2009; SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to summarise quantitative data into percentages of responses or respondents. Qualitative data collected, especially during the FGDs were summarised and presented in tables or used to explain patterns in quantitative results.

3. Results

Socio-demographic characteristics

About an equal proportion of males (51%) and females (49%) were interviewed in Uganda. In Rwanda, more males (57%) than females (43%) were interviewed, while in Burundi, a majority of the respondents (91%) were males. The head of households in Uganda and Burundi were predominantly males (72% and 91%, respectively) while less than half (47%) of the households in Rwanda were male headed. Most of the respondents in Uganda and Burundi were married adults (over 18 years) while in Rwanda, most respondents (66%) were youth (13–18 years). In all the three counties, more than a half of the respondents had at least attained primary school education. Farming constituted the major source of livelihood for most of the respondents (84% in Uganda, 94% in Burundi and 60% in Rwanda) followed by business and wage earnings.

Collection and use of edible insects

Results showed that a total of 20 edible insect types were collected and consumed in Uganda, 13 in Burundi and 6 in Rwanda (Supplementary Table S1). The most commonly reported EIs in Uganda were *Macrotermes subhyalinus* (62%), *Pseudacanthotermes militaris* (59%), *Ruspolia differens* (56%) and *Macrotermes bellicosus* (54%). The rest of the insects were each reported by less than 20% of the respondents. A total of nine edible insect types reported in Uganda were termite species. The commonly eaten castes of the termites are the alates of all the termites irrespective of the species). Other castes including the queen and soldiers were reported to be occasionally eaten, especially by children. The alates of *Macrotermes falciger* and *M. subhyalinus*, were reported to be collected and consumed in most households in Burundi and Rwanda, respectively. The most common source of insects consumed were households own collections and purchases from the markets (Supplementary Table S1).

Methods of collecting edible insects

Through FGDs, local communities described the steps taken to collect different EIs. The harvesting of EIs is mostly done by women and children, however men were reported to be involved in collecting insects with high commercial value such as *Macrotermes* and *R. differens*. The method of collection mainly depends on insects' behaviour. For example, night flying insects such as termites and *R. differens* were reported to be lured into traps by bright lights. The larvae of the palm weevil (*R. phoenicis*), which is restricted to the breeding sites (trunk of palm trees), are collected after detection followed by felling and splitting of the inhabited trees. Crickets and cicadas were reported to be detected through the sound they make. In all cases, locally available materials were used for collection. Some of the common tools used for collection of EIs included sticks, light bulbs, polythene bags, drums, buckets, baskets, saucepans, basins, iron sheets and tarpaulins. The methods for collecting EIs in Burundi and Rwanda were found to be more or less similar, mainly because the communities are ethnically close. The different methods for collecting the common EIs in the three study countries are hereby described:

Collection of Pseudacanthotermes militaris in Uganda

Once the emergence vents for alates (locally referred to as the 'eyes') have been sighted, a collection hole is dug. A dome-shaped framework is then constructed above the ground exhibiting the vents using flexible reeds from readily available plants such as *Lantana camara*, which are fixed into the ground. The structure is then covered with opaque materials, such as, clothes, grass and banana

leaves (communities had a conviction that the use of old clothes attracts more *Pseudacanthotermes millitaris* alates compared to new ones). However, a transparent polythene material is used to cover the portion of the structure above the collection hole in order to allow in sunlight which attracts the insect into the hole. A container, which can be a polythene bag or small bucket is placed inside the collection hole to protect the catch from contamination with soil. When the alates stop emerging from the ground, those trapped in the collection hole are removed by hand and packed into polythene bags for transportation. The collection exercise usually starts from mid-day (construction of the structure) and lasts up to 5:00 pm during rainy seasons. Alates of *P. millitaris* can also be stimulated to fly or emerge from the ground during dry periods, in which case, the exercise starts in the morning hours by watering and beating the ground surface (imitating rainfall). However, no such stimulation is required during rainy periods.

Collection of *Macrotermes subhyalinus* in Uganda

Collection of *M. subhyalinus* usually takes place at night. Alates emerge/fly out of the mounds between 8:00 pm-11:00 pm. During their expected period, mounds are checked for appearance of alate emergence vents on the mound between 8:00 am-2:00 pm. Once the vents are seen, an alate collection hole is dug at the base of the mound. A source of light, such as a lamp or grass torch, is used to attract the insects to the collection hole and/or container, e.g. saucepan, bucket, basin. Sometimes the vents are smoked with tobacco leaves or bark cloth to fasten the emergence of the insects.

Collection of *Macrotermes bellicosus* in Uganda

The method for collecting *M. bellicosus* is similar to that used for collecting *P. millitaris*. Usually the alates start to fly by 3:00 am. Vents/eyes are usually detected around 12:00 noon. Construction of a structure for a shelter to enclose the mound then starts and size of the structure depends on the size of the mound. Reeds used for this structure are bigger than those used for the *P. millitaris*. The frame is covered with grass, banana leaves but not clothes. The alates of *M. bellicosus* normally swam at the beginning of the first wet season (February-March), but some local people pour water onto the mounds during the end of the dry season to stimulate early swarming of the alates.

Collection of *Odontotermes kibarensis* in Uganda

After identifying the vents, a hand hoe is used to enlarge and expose the vents. The exposed and enlarged vents are then covered with small lumps of moist clay soil. More clay soil is then used to construct a channel connecting all

vents and lead up to a collection container which is fixed at the exit of the main channel. Some leaves are fixed at the entrance of the container to attract and direct insects towards the container. A small hole is also left above the collecting container to let in some light. Ground beating is done continuously to stimulate the flow of insects. As a taboo, the first alates to emerge should not be tasted as this was perceived to stop insects from emerging leading to a low catch and thus a waste of effort. Alternatively, *Odontotermes kibarensis* can be collected by digging a collection hole after noticing the vents, placing a clean container inside the collection hole (e.g. saucepan), placing a light source above the hole and beating the ground. The insects will keep following the light as they fall into a collection container.

Collection of *Ruspolia differens* in Uganda

Equipment required for commercial collection of *R. differens* include drums, white iron sheets (to reflect light), raised platform for placing drums (wooden platform or flat building top), high voltage electric wires, and electric bulbs (400-1000 W or 6,000-15,000 lm), capacitors for power stabilisation and sacs for bulking insects. Drums are placed on a platform in a row and one iron sheet is placed slanting into each drum with the upper part being supported by a wooden structure. The iron sheet is always placed against the direction of the wind so as to trap more *R. differens*. High voltage bulbs are then placed above the iron sheets. The lights are switch on by 7:00 pm so that swarming *R. differens* are attracted by the bright light. Flying *R. differens* attracted by the strong light will hit the iron sheet placed in the drum in a slanting position and eventually fall inside the drum whose inside is coated with moisten cassava flour and/or cooking oil making it slippery for trapped insects to climb out. Smoke from herbaceous plants is also applied in the collection site to attract more *R. differens*. Communities claimed that the smoke makes the insects 'drunk' (apparently inducing docility through intoxication), thus facilitating increased catches. Collected *R. differens* are regularly emptied from the drums into sacks when $\frac{3}{4}$ full.

Collection of *Rhynchophorus phoenicis* in Uganda

Collection of *Rhynchophorus phoenicis* starts with the identification of palm trees infested by *R. phoenicis* larvae. The common signs were reported to be drying foliage and holes on the upper part of the trunk. The harvesters are skilled in detecting infested trees that have more mature larvae by hitting the trunk with hands or a stick and listening to a characteristic cracking sound made by the larvae as they feed on the internal tissues of infested palm trees. Collectors are also skilled in detecting the infested portions of the tree trunk and this is used to avoid wasting energy in splitting the whole tree trunk. The infested tree is then

felled and the trunk split open with an axe so as to expose the larvae which are then hand-picked from their feeding chambers in the tree trunk and collected in saucepans or other appropriate containers.

Collection of *Macrotermes falciger* and *Pseudacanthotermes spiniger* in Burundi and Rwanda

The methods used for collection of *M. falciger*, and *Pseudacanthotermes spiniger* in Burundi and Rwanda are similar to those used for collection of *P. millitaris* and *M. bellicosus* in Uganda (described above). The only exception is that grasses and leaves are mainly used for covering the structure in the case of Burundi. The structure is built using sticks from *Bambusa aureostriata* or other tree branches, such as *Grevillea robusta*, *Dodonea viscosa* and *Eucalyptus* sp. These trees are preferred for their pliability. The constructed structure is covered using grasses from species such as *Imperata cylindrical* and *Loudetia simplex*, or banana leaves and tarpaulins.

Collection of other edible insects in Burundi and Rwanda

The collection of other EIs in Burundi and Rwanda does not require the construction of a structure. Rather, they are simply hand-picked and placed in a bag or any other appropriate utensil. The alates are generally stimulated to emerge from the ground by beating a piece of wood or bamboo stem partially buried in the ground for about five hours. However, *Pseudacanthotermes* are captured during the night. They are attracted by light (from kerosene lamps or touches). *Pseudacanthotermes* sp. always crawl around the light source where they are hand-picked.

Preference for different edible insects and time of availability

In Uganda, communities mostly preferred *R. differens* because it is fatty and tasty. Termite alates were the second most preferred edible insect in Uganda. Among the termite species reported in Uganda, alates of *P. millitaris*, *M. subhyalinus* and *M. bellicosus* were the top most preferred in relation to their taste and abundance (Table 1). In Burundi, *M. falciger* was ranked first followed by *Carebara vidua* and *P. spiniger*. Like in Uganda, *R. differens* was ranked highest in Rwanda and it was followed by *M. subhyalinus*. Much as *R. differens* was ranked highest according to taste in Uganda and Rwanda, termite alates were ranked the most abundant in the two countries followed by *R. differens*.

In all the study sites, EIs were available at different months and were harvested at specific times of the day. In Uganda for instance, the key EIs seemed to be available throughout the year except for January and October. For example *M. bellicosus* and *Odontotermes* spp. were reported to be available in February followed by *B. membranaceus* in

March and *M. subhyalinus* in April. *C. vidua* was available from May to June while *R. differens* was in abundance from April to July and again from November to December. *P. millitaris* filled the gap from August to September (Table 1).

The larvae of palm weevil (*R. phoenicis*), were reported to be consumed only in Kalangala district in Uganda. This species was ranked the most preferred edible insect by far in the district due to its delicacy. A single fried *Rhynchophorus* larva was reported to cost UGX 200 (about USD 0.06) and that elders, usually unable to collect the insect on their own, were willing to exchange a cup-full of about 50 *Rhynchophorus* larvae with a mature cock. The islanders in Kalangala reported *Rhynchophorus* larvae to be available throughout the year, but more abundant from May to July. During harvesting, the host palm tree is destroyed in the process since it involves felling the tree and splitting the stem.

Preference for the different edible insect species apparently varied among different categories of household members. In Uganda, consumption of *Acanthacris ruficornis*, *Ugada limbalis* and *Brachytrupes membranaceus* was predominantly by children. Over 50% of the respondents in Uganda who consumed *P. millitaris*, *M. subhyalinus*, *M. bellicosus* and *R. differens* mentioned the consumption of these insects mainly by men, women and children. Similarly, when asked about the consumption of alates generally, most respondents in Uganda reported children (78%), women (72%) and men (69%) as the main consumers. Relatively fewer respondents reported elders as the main consumers of EIs when compared to the other cohorts in the household. In Rwanda, children were the major consumers of EIs (over 67%) (Table 2).

Up to 86% of the respondents in Uganda reported that children should be encouraged to eat EIs. Almost three quarter of the respondents were of the opinion that people need to be encouraged to eat EIs. In Burundi and Rwanda, all the respondents reported that all the age groups should be encouraged to consume EIs. The major reasons for encouraging the different age groups to consume EIs included: perceived high nutritional value, good taste (delicacy), EIs are part of their culture, and increased interest by all age categories.

Processing and storage of edible insects

Although a number of insects were eaten raw, most respondents preferred frying or roasting them prior to eating. Sun drying of fried insects was also common, especially for *R. differens* and termite species (*P. millitaris*, *M. bellicosus*, *M. subhyalinus* and *O. kibarensis*) (Figure 1). A few respondents (5%) in Uganda reported processing of *M. subhyalinus* into a paste. Activities reported to be conducted during processing of EIs include sorting,

Table 1. Local preference of edible insects and knowledge of their temporal occurrence.

Site/Insect	Rank ¹		Months and time of occurrence
	Taste	Abundance	
Uganda (n=120)			
<i>Ruspolia differens</i> (Ensenene)	1	2	April-July; November-December (8 pm-3 am)
Alates (Enswa)	2	1	
<i>Macrotermes bellicosus</i> (Empau) ²	(3)	(2)	February (2 am)
<i>Macrotermes subhyalinus</i> (Ensedhere) ²	(2)	(1)	April (2 am)
<i>Pseudacanthotermes millitaris</i> (Naka) ²	(1)	(3)	August-September (1-4 pm)
<i>Odontotermes kibarensis</i> (Emegere) ²	(7)	(4)	August (4-7 pm)
<i>Pseudacanthotermes</i> sp.2 (Entukutuku) ²	(8)	(7)	April (4-7 pm)
<i>Pseudacanthotermes</i> sp.1 (Amaabuli) ²	(6)	(5)	July (7 pm)
<i>Odontotermes</i> species (Emoke) ²	(4)	(6)	February (4-7 pm; 4-6 am)
<i>Pseudacanthotermes spiniger</i> (Entunda) ²	(5)	(8)	August (5-6 pm)
<i>Pseudacanthotermes</i> sp.5 (Ensulamiriri) ²	(9)	(9)	April (1 pm)
<i>Carebara vidua</i> (Ebyadidi)	(10)	(10)	May-June
<i>Nomadacris septemfasciata</i> (Enzige)	3	6	periodic/occasional
<i>Brachytrupes membranaceus</i> (Ekiyende)	4	4	February-March
<i>Acanthacris ruficornis</i> (Ebidhede)	5	3	Throughout the year (January-December)
<i>Ugada limbalis</i> (Enziira)	6	5	Throughout the year (January-December)
Burundi (n=60)			
<i>Macrotermes falciger</i> (Inswa)	1	1	November-December (9 am-2 pm)
<i>Pseudacanthotermes spiniger</i> (Intunda)	3	2	December (4-6 pm)
<i>Carebara vidua</i> (Ibitemvu)	2	4	September (10-11 am)
Unidentified (Insana)	4	3	March (6-1 pm)
Unidentified (Inyamuneka)	5	7	December (4-6 pm)
<i>Pseudacanthotermes</i> sp. 4 (Ingorogoro)	8	5	November (4-6 pm)
Unidentified (Imyumvuri)	7	8	November (4-7 am)
Unidentified (Ikindara)	6	6	September (6-7 pm)
Unidentified (Imbwambwa)	9	9	November-December (5-7 pm)
Rwanda (n=90)			
<i>Ruspolia differens</i> (Isenene)	1	2	April-May
<i>Macrotermes subhyalinus</i> (Inswa)	2	1	January-April
<i>Macrotermes</i> species (Iswegegere)	1	2	September-December

¹ The ranks in parenthesis apply only to the different types of alates.

² Denotes insects that form the different types of alates in Uganda and names in parentheses are local names.

washing, and removal of wings and legs. Removal of legs was mostly done on *Orthoptera* species (*R. differens*, *B. membranaceus* and *A. ruficornis*) while removal of wings was most commonly reported on both the *Orthoptera* and *Macrotermes* species (*M. subhyalinus*, *M. bellicosus* and *M. falciger*). In all three study countries, processing of EIs was mostly done by women (77%), followed by children (40%), men (17%) and the elderly (13%). A few respondents (9%) pointed out the benefits of processing insects to include: improving taste and quality (58%), enabling incorporation of the insects as food supplement (52%), and increasing income through extended selling period (7%).

Conservation and rearing of edible insects

In all the three countries, communities could not easily guarantee the conservation of EIs. In most cases, EIs were considered to be God-given, and as such, there is no need to conserve or rear. Farming activities were reported to be greatly affecting the abundance of many EIs, for instance, destruction of termite mounds has reduced the abundance of the alates. Termites were reported to be destructive to maize crop in Iganga district, Uganda, resulting in yield losses of up to 50% of the potential harvest. No attempts of EIs rearing were reported in all the project sites but tree planting was pointed out as a way of increasing the

Table 2. Category of people who mainly eat insects in household.¹

Site/Insect	Men	Women	Children	Elderly
Uganda (n=120)				
<i>Ruspolia differens</i> (Nsenene)	75.0	77.9	92.6	33.8
<i>Macrotermes bellicosus</i> (Mpawu)	73.5	65.3	69.4	28.6
<i>Pseudacanthotermes militaris</i> (Naka)	72.0	68.9	83.6	45.9
<i>Macrotermes subhyalinus</i> (Ensedhere)	71.7	55.0	61.7	25.0
<i>Odontotermes kibarensis</i> (Emegere)	66.7	41.7	5.0	25.0
<i>Acanthacris ruficornis</i> (Ebidhede)	37.2	28.1	90.8	28.1
<i>Pseudacanthotermes</i> sp.1 (Amaabuli)	33.3	88.9	88.9	22.2
<i>Ugada limbalis</i> (Enziira)	25.0	50.0	75.0	25.0
<i>Brachytripes membranaceus</i> (Ekiyende)	24.2	29.7	97.8	13.6
<i>Odontotermes</i> species (Emoke)	2.3	2.3	1.6	1.6
<i>Carebara vidua</i> (Ebyadidi)	2.3	66.7	66.7	33.3
Burundi (n=60)				
<i>Macrotermes falciger</i> (Inswa)	100.0	100.0	100.0	21.4
<i>Carebara vidua</i> (Ibitemvu)	60.0	60.0	58.6	11.4
<i>Pseudacanthotermes spiniger</i> (Intunda)	41.4	41.4	41.4	11.4
Unidentified (Ikinyabobo)	31.4	22.9	22.9	4.3
Unidentified (Insana)	24.3	24.3	24.3	4.3
Unidentified (Inyamuneka)	22.9	22.9	22.9	8.6
Unidentified (Umuwuri)	17.1	17.1	17.1	1.4
<i>Pseudacanthotermes</i> sp. 3 (Ingorogoro)	14.3	14.3	14.3	2.9
Unidentified (Agacumbugu)	8.6	8.6	8.6	1.4
<i>Ruspolia differens</i> (Insenene)	8.6	8.6	8.6	1.4
Rwanda (n=90)				
<i>Ruspolia differens</i> (Insenene)	43.8	60.9	85.9	3.1
<i>Macrotermes subhyalinus</i> (Inswa)	27.8	66.7	94.4	11.1
<i>Pachylomera fermoralis</i> (Ibihori/Igihere)	50.0	50.0	83.3	8.3
Unidentified (Ijeri)	50.0	50.0	0.0	50.0
Unidentified (Ihanzi)	66.7	66.7	66.7	0.0
<i>Macrotermes</i> species (Iswegegere)	33.3	100.0	100.0	0.0

¹ Insect names in parentheses are local names. Species reported as eaten by 2 or fewer respondents were excluded.

abundance of some EIs. Additionally, there are no by-laws for conserving EIs in all the study sites in the three countries.

Cultural beliefs and values

The common cultural beliefs relating to the collection and consumption of EIs reported include: women eat *U. limbalis* to sharpen their voices; a woman who has just produced twins is not supposed to eat *R. differens* as it is believed to bring bad luck; and *A. ruficornis* can be cut and the internal parts placed on the woman's breast to initiate milk flow in order to feed a foster child. In addition to their food values, EIs were also considered as important for medicine, income, gifts, feed for poultry, and bait for birds and fish. A total of five edible insect species were reported to be used as medicine with *B. membranaceus*

(67%) being the most commonly cited for this purpose. A number of termite species (*P. militaris*, *M. bellicosus*, *M. falciger*, *M. subhyalinus* and *O. kibarensis*) were reported to be used for income generation and to a lesser extent as baits (for fish and birds), feeds and gifts.

Challenges in collection and processing of edible insects

A number of challenges were reported in the collection and processing of EIs. Major challenges cited during collection included lack of appropriate collection containers, contamination with unpalatable insects and soil, and accidents during collection. For commercial collection of *R. differens*, power black-outs was a major concern as well as blowing up of power meters due to high wattage of the bulbs used leading to low catches. Communities also reported a serious health risk arising from the use of bright/



Figure 1. Examples of locally processed edible insects ready for consumption: (A) fried *Ruspolia differens*, (B) fried *Rhynchophorus* larvae, (C) fried *Pseudacanthotermes millitaris*, and (D) fresh and cleaned *P. millitaris* packed in banana leaves.

strong light in collection of *R. differens* which affects the eyes. Repeated exposure to such strong light was reported to cause damage to the skin. Cases of electric shocks were also reported by the commercial collectors. Key challenges during processing included difficulties in drying of insects due to weather changes that are unpredictable during the collection period, perishability of EIs and the laborious and time consuming process of cleaning EIs (e.g. removal wings, legs and other appendages for *R. differens*).

4. Discussion

Local communities reported several species of insects consumed in their households or by their neighbours and a majority of them considered EIs as an important source of nutrients to all categories of people. These results reaffirm that insects are an integral part of the diet among local communities in LVB. Similar findings have been reported for Sub-Saharan Africa (Van Huis, 2003) and other parts of the world (Durst *et al.*, 2010). The consumption of the highly rated African palm weevil, *R. phoenices*, in Kalangala is apparently documented for the first time in Uganda. The insect has also been reported to be consumed in some Central and West African countries (Muafor *et al.*, 2015; Van Huis, 2003). In the lowlands of Papua Guinea, the larvae of *Rhynchophorus bilineatus* (sago beetle) has been reported as the most important edible insect to the Citak and Asmat people (Ramandey and Van Mastrigt, 2010).

The larvae of *Rhynchophorus* species is also known to be consumed in Peru (Delgado *et al.*, 2008). The importance attached to EIs such as *Rhynchophorus* larvae by distant local communities in Africa, Australia, Asia and South America does not only indicate the nutritional importance of the insects, but also its regional and global market potential that should be exploited. Most of the EIs collected were for own consumption, however, species such as *R. differens*, *R. phoenices* and some *Macrotermes* species were sold to generate household income. Van Huis (2003) noted that the sale of insects yields more revenue for farmers than millet in the Sahel and observed that small-scale production units with simple techniques for mass rearing of insects can be initiated in such areas.

Except for the collection of *R. differens* in Uganda, the methods used for collecting EIs, their processing and storage reported in this study indicate that the use of EIs in LVB and indeed entire East Africa has remained largely traditional and underdeveloped. Local communities enumerated a number of challenges associated with this process which need to be addressed. Emphasis needs to be placed in developing technologies aimed at ensuring purity during collection, processing and storage. The traditional method of hand beating flying EIs with tree branches such as *R. differens* as is done in Rwanda and Burundi is laborious and limits the catches. Gahukar (2011) observed that collecting a large quantity of insects in the wild is

often uncertain due to their unpredictable locations and population density. Research on management potential of wild EIs could enhance harvests, ensure sustainability and create potential economic viability of mass collection. This can ultimately contribute to rural food stock for improving livelihood of the local people. Development of economically feasible ways of mass rearing of EIs in closed environments is also crucial since most insects are only seasonally available in nature (Sileshi and Kenis, 2010).

Innovative insect trapping methods such as the drum catching of *R. differens* reported in Uganda seems attractive for maximising catches, but requires improvement with particular attention paid to the health hazards associated with the high voltage bulbs. The promotion of such power-based technologies means that rural communities without electrical installations may be disadvantaged in collecting *R. differens* since they are easily attracted to bright lights. The islanders in Kalangala reported that the use of strong lights for attracting *R. differens* in the mainland had drastically reduced the catches in the island, leaving them as net buyers of the insect which used to be abundant in the near past. Low cost technologies involving the use of lamps and generators need to be evaluated for such communities. The use of lamps for catching termites which swarm at night seem more appropriate than the traditional grass torches, which produces burnt debris that can easily contaminate the insects collected. The cleaning of insects through removal of wings and legs, remain challenging, more especially at commercial scales, and calls for technologies specific to insect types. Priority for such technologies needs to be given to species that are collected in high quantities and have high commercial value such as *Ruspolia* and termite species. To manage insects in the interest of food security, more attention should be given to environmentally sustainable harvesting methods. Such harvesting methods should conserve the areas where EIs are found. Edible insects could be made available throughout the year by developing improved conservation methods or by farming them as mini-livestock (DeFoliart, 1992; Fasoranti and Ajiboye, 1993; Kelemu *et al.*, 2015; Van Huis, 2003). In addition, cost-effective rearing, harvesting and processing technologies are required to prevent depletion and ecological perturbations while ensuring continuous availability of insect-based products.

Harvesting of palm weevil (*R. phoenicis*) resulted in killing of the host plant. Local harvesters pointed out that every tree infested by *Rhynchophorus* eventually dies due to extensive tree trunk boring by the insect. The palm trees mainly grow in wetland areas (swamp forest) and, in Uganda, these are protected by wetland laws. The area surrounding the study site in Kalangala has a large commercial oil palm plantation. However, much of the swamp forests were not converted for oil palm cultivation because they are located

in a conservation area. It was also reported that the palm oil company was not actively involved in management of these forest patches. DeFoliart (2005) pointed out a need to link forest management practices with insect conservation to facilitate sustainable harvesting of EIs. The reasoning is that entomophagy can make a significant contribution to EIs conservation if insects are sustainably harvested.

In all the study sites, EIs were available at different times of the year and were harvested at specific times of the day. According to the respondents, this staggered availability of different EIs was important in ensuring food security at different times of the year. Most EIs were generally available during the start of the rains when food reserves were low, thus helping to fill the food gap. Some EIs collected in large quantities (*R. differens*, *R. phoenicis* and termite alates) were sold to generate income for purchasing food and other household necessities. This points to the contribution of EIs to food security in LVB.

The fact that no efforts were geared towards conservation of EIs is alarming, especially considering the ever diminishing habitats for insects and the emerging impacts of climate change. Communities reported that over-harvesting of EIs in LVB is already leading to decline in insect populations. Yen (2009) reported that insect populations are often diminished due to commercial exploitation, bush fire, unfavourable climatic factors and attack by natural enemies. Communities in LVB reported that climate change has led to a decrease in some insect populations resulting in diminished catches. Additionally, the collection periods for some EIs have also been affected. As indicated by Van Huis *et al.* (2013), this calls for extensive community sensitisation campaigns and development of guidelines to address grass root conservation challenges. Such guidelines should be founded on sound knowledge of the biology and ecology of the different insects as well as the local practices and beliefs. For example, none of the communities surveyed was knowledgeable about the breeding habitats of the highly valued *R. differens*, with some claiming that the insects are God-given and come from heaven. With such beliefs, local communities can easily destroy vital habitats for this insect, expecting God to continue providing the insects from heaven for eternity. Except for EIs with high commercial values like *R. differens*, most EIs were harvested by women and children. A review by Van Huis (2003) reported similar findings and it was noted that insect farming can be a low-input sustainable form of agriculture for women and children. In order to increase use of insects as food, promotional and educational aspects about insects should be encouraged and these include assurance of quality and safety of insect products (Gahukar, 2011).

5. Conclusions

This study has demonstrated the importance of EIs to the livelihood of rural communities in LVB, thereby underscoring the need to develop this industry. We documented, for the first time, local knowledge on the use and consumption of EIs in LVB at a regional level. Local communities across the region are faced with several challenges associated with the collection, processing and storage of EIs. This requires urgent attention focusing on the development of appropriate technologies for commercially viable EIs. It is evident that conservation of EIs or their habitats is not considered by local communities, posing a threat to the sustainable utilisation of EIs in the region. Communities need to be sensitised on conservation issues pertaining to EIs insects for sustainability purposes. There is also need to provide evidence on nutritional values of EIs consumed in LVB so as to promote their wide use, commercialisation and conservation. Future studies could also focus on assessing the abundance and seasonality of EIs in LVB as well as rearing potential. Such information could be important in designing environmental conservation as well as breeding programmes for priority EIs in the region and elsewhere. Future studies could also look at the economic returns from trade in EIs within LVB. Such studies will espouse the economic potential of EIs as a tool for poverty eradication and a source of livelihood.

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Supplementary material

Supplementary material can be found online at <https://doi.org/10.3920/JIFF2016.0051>.

Table S1. Edible insects collected and their sources in households.

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