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REVIEW

Observations of entomophagy across Benin – practices and potentials

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Abstract Food security is a critical issue for many low-income countries, particularly in Sub-Saharan Africa. Appropriately identifying and utilising local resources can provide sustainable solutions to food security problems. Insects, which are traditionally consumed in many regions of the world, represent one such resource. Insects can be nutritionally rich and therefore could be used to address issues of malnutrition. A first step towards utilising insects as a resource is identifying which ones are traditionally consumed. We present data collected between 2005 and 2012 on insects eaten by communities across Benin, West Africa. A combination of literature research, field collections, community focus groups and targeted interviews were employed. Data on four ethnic groups is presented: the Anii, Fon, Nagot and Waama. Twenty-nine arthropods species are eaten across Benin. The predominant orders are Orthoptera (48 %) and Coleoptera (41 %). New families of edible arthropods in West Africa include: Bradyporidae (Orthoptera), Coreidae (Hemiptera), Dytiscidae (Coleoptera), Ixodidae (Acari). Insect collection is an ancestral tradition in all the described communities: however, there are considerable differences in preferences and collection methods among ethnic groups. Currently there is little valorisation of insects as a food product in Benin, in contrast to neighbouring countries. In light of considerable malnutrition in Benin among young children, promoting this tradition and implementing small scale captive rearing of selected species could improve food security.

Keywords West Africa · Edible insects · Malnutrition · Food security · Mini-livestock · Sustainable agriculture · Local traditions

Background

Food security is one of the major challenges of the current century (FAO 2013). As the global population is projected to reach 9.6 billion by 2050 (UN et al. 2014), attempts to increase arable land area will increasingly come into conflict with other land uses. Current livestock production, including feed-crop production, occupies approximately 70 % of the world's agricultural land (30 % of the earth's land), and consumes 77 million tonnes of plant or animal protein to produce just 58 million tonnes of protein for human consumption annually (Steinfeld et al. 2006). To meet the nutritional needs, considering projected growth in the human population, agricultural production will have to increase substantially, eventually doubling current production by 2050 (FAO 2009). This increasing pressure on land is making future meat production from livestock unsustainable on a global scale. In particular, food security is a critical issue for low-income countries that already struggle to meet their nutritional needs (FAO 2009).

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Despite recent economic and social improvements in certain areas (World Bank 2014), countries in Sub-Saharan Africa, such as Benin, still have the lowest average animal protein intake per capita per day in the world (WHO 2014). Benin remains among the poorest countries in the world (rank 167 of 187 Human Development Index (HDI) with 51.6 % of the population living on less than $US1 a day (BTI 2012). In addition it has one of the highest demographic growth rates (rank 14 of 240 countries). In particular, child malnutrition (i.e., affecting children under the age of five) is a serious problem, with studies showing that moderate and severe stunting is increasing (from 25 % in 1996 to 27 % in 2001 and then 35 % in 2006) (UNIDEA 2006) .[1] Given the ill effects of economic fragility, climate change, as well as a lack of management and planning concerning food security, the value of alternative local sources of protein becomes immediately apparent for communities in Benin (FAO 2013; Illgner and Nel 2000).

The practice of eating insects, known as entomophagy, is common in many parts of the world. About 2000 species of insects are traditionally eaten worldwide (Jongema 2013), with many forming an important part of the diet and economy in several societies (Merle 1958; DeFoliart 1995). In contrast to comparatively resource intensive, expensive and high risk forms of livestock, insects offer many valuable benefits, especially when considering farming. Insects offer similar or superior quality of nutrition compared to other livestock (van Huis 2003; Belluco et al. 2013; Rumpold and Schlüter 2013). In addition, they have a higher energy conversion rate (Lindroth 1993) and thereby lower consumption of natural resources (Nakagaki and DeFoliart 1991; Oonincx and de Boer 2012), higher fecundity and a faster growth rate. Increasingly, it is being recognised that entomophagy is an option which deserves urgent global attention (Premalatha et al. 2011; van Huis 2013; FAO 2013). However, farming insects for food and feed has largely been absent from agricultural innovations in livestock farming that emerged in past centuries (van Huis 2013).

The consumption of insects is widespread throughout the African continent with some 250 species being consumed, either as important components of the daily diet or as delicacies that are sold in markets and even exported (van Huis 2003). For example, in the in Kwango District of the Democratic Republic of Congo, insects constitute up to 64 % of the animal protein consumed by humans (DeFoliart 1999). In addition, some agricultural pests are edible and used as food by certain communities, for example locusts (Ramos-Elorduy 1997; Cerritos and Cano-Santana 2008). In South Africa, the potential of large scale entomophagy is well illustrated through the mopane caterpillar (*Imbrasia belina*) industry, which forms the basis of a multi-million dollar trade in edible insects, providing livelihood for many harvesters, traders and their families (FAO 2004). However, across Africa there is huge variation in entomophagy habits (van Huis 2003). Case specific studies investigating local preferences and practices are therefore important for managing and promoting traditions suitable to individual communities' needs.

In Benin, insects have been and still are traditionally consumed. However, formal studies in this region remain limited, with only a preliminary list existing for those insects consumed in southern Benin (Tchibozo et al. 2004). Nonetheless, they represent an important source of animal protein in the South, which suggests that edible insects could contribute to the prevention and alleviation of malnutrition (Tchibozo et al. 2004). While the benefits of entomophagy are apparent, there has been little consideration of how to realise the full potential of insects as food in Benin. This paper offers a review of arthropods currently eaten across the country. The report concentrates on four ethnic groups known to consume insects: the Anii, the Fon, the Nagot and the Waama. The different species eaten regionally are listed alongside species specific information and the collection methods used by the communities. Their significance to people's livelihoods, from their collection for subsistence to the potential of insect farming, are also explored.

Materials and methods

Studied groups

This study focused on four communities spread across Benin (See Appendix 1 for map locations across Benin). Two Waama settlements, Kosso and Cotiakou, were visited in the North. This area is characterised by one rainy season from June until October and by a long dry season from December until March. The Anii village of Pénélan in the centre and the Nagot communities, Issaba and Pobé, and the Fon village of Lokoli in the South occur in the area of the country characterised by a more tropical and humid environment, with two rainy seasons from April until July and a shorter one in October. A more detailed table about the groups with respect to the overall ethnic diversity of Benin can be found in Table 1.

Field methods

Information on the insect species collected was assembled through literature research, field collections, community focus groups, and selected interviews. For the Anii, the Fon, and the Nagot communities, data were collected in 2005 and 2010

[1] Malnutrition is defined by the World Food Programme as 'state in which the physical function of an individual is impaired (due to poor nutrition) to the point where he or she can no longer maintain natural bodily capacities' (WFP 2014).

Table 1 Descriptive table of the sites and communities visited in Benin

Date of study	Ethnic group	Proportions of the ethnic groups in Benin[a] (%)	Village	Coordinates	Number of visits	Collectors
Nov 2005 Nov 2010	Anii	0.3	Pénélan	09°15.05 N; 001°30.40E	7	ST[b]
Nov 2010	Nagot	6.8	Issaba	07°04.11 N; 002°38.50E	4	ST[b]
Sep 2010			Pobé	06°56.06 N; 002°39.09E	12	ST[b]
Oct 2010	Fon	17.6	Lokoli	06°22.07 N; 002°29.39E	20	ST[b]
Oct-Nov 2012	Waama	1.0	Kosso	10°36.44 N; 01°17.26E	16	LR, RV, MV, CM
Oct-Nov 2012			Cotiakou	10°35.58 N; 01°17.5E5	8	LR, RV, MV, CM

[a] Data from : INSAE (2003). Troisième recensement général de la population et de l'habitation – Février 2002

[b] Data from: Lincaocnet (nd)

(Lincaocnet, nd) and information concerning these communities was obtained from the Lincaocnet website and directly via interviews with the collectors. The Waama communities were visited in 2012. Comparable field methods were used for all investigated communities. Table 1 outlines the details of the dates and number of visits to the different communities. Field collections of insects were carried out within 5 km of the settlements with the community members who would traditionally be making the collections. The location, indigenous name, plant from which the insect was collected, method of collection, general habitat, and collection date of each morphospecies was noted. When possible four specimens of each insect were kept in 60 % ethanol and identification was carried out by specialists [International Institute of Tropical Agriculture in Cotonou, Agricultural Research for Development (CIRAD), Museum of Natural History Paris].

The community focus groups concentrated on the traditional, nutritional and medical uses of insects collected and documenting the preparation, cooking, and eating of different insect species. The focus groups were conducted with the administrative representative of the settlements and with members of the communities. For cultural reasons these groups mostly consisted of men between the ages of 10 and 45. Interviews were carried out either directly in French or by means of translation via a community member. To investigate the potential of developing entomophagy in general across Benin various specialists in the fields of entomology, food science, agribusiness, health and food security were also interviewed (Appendix 2).

Limitations

As the data were collected by two different parties (Table 1) minor discrepancies in methodologies and observations may have arisen, despite all efforts made to maintain consistency. However, it was not the intention of this study to quantify the availability or the usage of the species by the communities, but instead, to provide a descriptive ethnographic study to understand differences in usage of insects among ethnic groups in Benin and place them in context within West Africa. Another limitation of the project is the length of time spent in each community, which allowed the collection of most but not all insects that were eaten as a number of insects occur seasonally. By interviewing community members we were able to take note of species not available at the time of our sampling to give an estimate of when other species were consumed by the community. Language and cultural barriers can also create misunderstandings. However, repeated visits, having a large number of interviewees, and using local guides for translation aimed to minimise the significance of this problem.

Results

Insect species consumed

Results from a total of 67 village visits reveal that 29 arthropod species from 12 families are eaten across Benin (Table 2). Novel families to West Africa recorded in the present study were Bradyporidae (Orthoptera), Coreidae (Hemiptera) and Ixodidae (Acari) of which Ixodidae and Bradyporidae are also novel worldwide. Between ethnic groups there is great specificity in what species of insects they are willing to consume, in particular in the life stage of insect they utilise (Table 2). The Waama have the most diverse assemblage of edible arthropods, consuming 18 different species. The Nagot

Table 2 List of arthropod species consumed by four communities across Benin

Order	Family	Species	Habitat	Group	Local Name	Size of eaten specimen (cm)	Developmental stage
Orthoptera	Acrididae	*Acanthacris ruficornis* (Serville)	Bush grass, Okra	Waama	Manchougou	5	adult
	Acrididae	Gomphocerinae sp.	Bush grass	Nagot	Igbe	5–7	adult
	Acrididae	*Hieroglyphus africanus* Uvarov	Bush grass	Waama	Sosore	5–7	adult
	Acrididae	*Locusta migratoria* (L.)	Bush grass, coconut trees	Anii	Goutanta	5–7	adult
	Acrididae	*Ornithacris turbida* (Walker)	Bush grass, Okra	Waama	Manchougou	5	adult
	Acrididae	*Spathosternum pygmaeum* Karsch	Bush grass	Nagot	Igbe	5–7	adult
	Acrididae	*Truxalis* spp.	Bush grass	Waama	Chaubafranca	7	adult
			Rotting coconut trees	Anii	Goutanta	6–8	
	Bradyporidae	*Gymnoproctus sculpturatus* Schmidt	Bush grass, millet	Waama	Nagitasambi	4–5	adult
	Gryllidae	*Brachytrupes membranaceus* Drury	Burrows under mango trees	Waama Anii	Baga Afomon	4–5	adult
	Pyrgomorphidae	*Zonocerus variegatus* (L.)	Bush grass	Nagot	Alankpa	5–7	adult
	Tettigoniidae	*Conocephalus* sp.	Bush grass	Nagot	Igbe	5–7	adult
	Tettigoniidae	*Pseudorhyncus* sp.	Bush grass	Anii	Guegbele	5–7	adult
	Tettigoniidae	*Ruspolia* sp.	Bush grass	Anii	Guegbele	5–7	adult
Coleoptera	Buprestidae	*Sterapsis castanea* (Olivier)	Acacia trees	Waama	Kokouanre	5	adult
	Buprestidae	*Sternocera interupta* (Olivier)	Acacia trees	Waama	Kokouanre	5	adult
	Dryophthoridae	*Rhynchophorus phoenicis* (Fab.)	Rotting oil palm wood	Nagot	Kpitran	3–4	larvae
	Dytiscidae	*Cybister* sp.	Still water pools	Waama	Cotondousre	3–4	adult
	Scarabaeidae	*Chondrorhina abbreviata* Fab. *Polybaphes* sp.	Bush grass, maize, millet	Waama	Pipirundi	2	adult
	Scarabaeidae	*Dynastinae* sp.	Rotting palm oil wood	Nagot	Woiwo	5	larvae
	Scarabaeidae	*Gnathocera varians* Gory & Percheron	Bush grass, maize, millet	Waama	Sopipiru	2	adult
	Scarabaeidae	*Gnathocera impressa* Olivier	Bush grass, maize, millet	Waama	Fapipiru	2	adult
	Scarabaeidae	*Oryctes* spp.	Rotting palm wood	Anii, Fon	Aposanga Atrandekpometon	5	larvae
	Scarabaeidae	*Pachnoda cordata* Drury	Bush grass, maize, millet	Waama	Pipiru	2	adult
	Scarabaeidae	*Pachnoda vossi* Kolbe	Bush grass, maize, millet	Waama	Pipisae	2	adult
	Scarabaeidae	*Rhabdotis bouchardi* Legrand	Bush grass, maize, millet	Waama	Fapipiru	2	adult
Isoptera	Termitidae	*Macrotermes bellicosus* (Smeathman)	Termite mounds	Waama, Anii,	Iiriri Iyeye	0.5–2	sexual winged adults
	Termitidae	*M. subhyalinus* Rambur.		Nagot	Etoutou		
Hemiptera	Coreidae	*Anoplocnemis curvipes* (Fab.)	Bush grass	Waama	Comocomo	3–4	adult
Ixodida	Ixodidae	Unknown	On cattle	Waama	Nagopta	0.5–1	all stages

and the Anii both consume seven species and only one species is eaten by the Fon. Preferences differ markedly between the Waama and the other groups. In the Waama the most commonly consumed arthropods were Coleoptera (52 %), of which they only ate adults, followed by Orthoptera (29 %). We observed that the most commonly eaten beetle is the scarabaeid *Pachnoda cordata* (Drury), however a detailed quantification of different species consumed would be needed to understand the true relative contribution of different species to local diets. The Nagot and the Anii have a noticeable predilection for Orthoptera (respectively 57 and 71 %) and eat Coleoptera only in their larval stage. The preferred species to eat in the South are the larvae of *Oryctes* spp. (Coleoptera, Scarabaeidae), *Rhynchophorus phoenicis* (Fab.) (Coleoptera, Dryophthoridae), and the adults of *Brachytrupes membranaceus* (Drury) (Orthoptera, Gryllidae). Some insects are shared across communities: winged termites are consumed by three of the four communities and both *B. membranaceus* adults and *Oryctes* spp. larvae are eaten by more than one group. The termite species was reported to be *Macrotermes falciger* (Gerstaecker) (Tchibozo et al. 2004). However, as this species is only known to inhabit South and central Africa, the actual identity of the termite must be *M. bellicosus* (Smeathman) or *M. subhyalinus* Rambur. In general most insect species eaten are unique to a particular ethnic group.

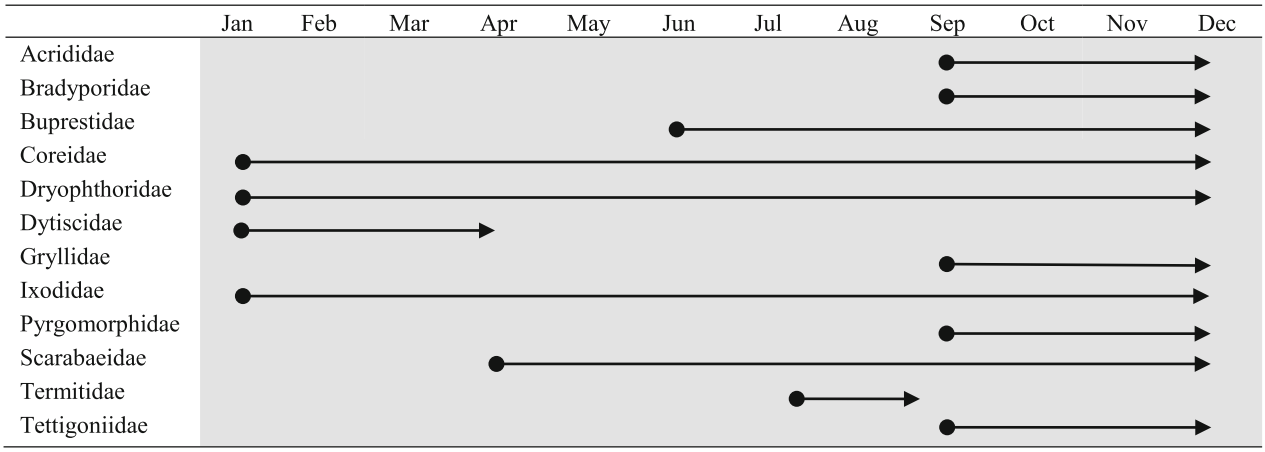
Orthoptera are generally collected in the bush grass and from crops, generally millet, around 0–5 km from settlements. It is likely that these are places where they are most conspicuous rather than the only locations where they occur. *Brachytrupes membranaceus* is an exception and is collected from burrows, generally under mango trees. Coleopterans are eaten as larvae and collected in decaying palm wood by the Nagot, the Anii and the Fon, or solely as adults by the Waama who collect them on the surrounding grasses. Exceptions for the Waama are species of the family Buprestidae whose adults are collected on Acacia trees and a species of water beetle, *Cybister* sp., collected in still water pools. The most favourable season for the gathering and collecting of insects is just before the start of the dry season, from October till December for most orthopterans and during the rainy season, from May to July, for coleopterans. Exceptions are *B. membranaceus*, which is collected earlier in the harvest season (September), the larvae of *R. phoenicis* in the South, which are collected all year round, and the water beetle *Cybister* sp., collected only in the North, which is available in the dry season (Jan-Apr) when stream water becomes stagnant. The latter could be an important source of protein in years of poor harvest (Dr. Aouanou, Hospital St Jean de Dieu, Tanguieta, Pers. Comm.). The result is that entomophagy changes with seasons, with distinct groups of species being eaten at different times (Table 3).

Several species collected in Benin are of particular interest. The bush cricket, *Gymnoproctus sculpturatus* Schmidt, is the first recorded presence in West Africa, previously, having only been found in East Africa (Schmidt 1990). With the present record, there are only three genera and species of armoured ground cricket known from West Africa. To our knowledge, this is also the first known record of a member of the genus *Gymnoproctus* being eaten worldwide. The species is large (4x2x2cm), slow moving, flightless and conspicuous when mature, being found wandering through the lower levels of bush grass and crops. It is both easy to catch and highly appreciated by the Waama. Secondly, we present a report of the water beetle *Cybister* sp. (Dytiscidae), of which there are only three other reports of similar species being eaten across Africa (in Senegal, Sierra Leone, D.R. Congo – Ramos-Elorduy et al. 2009). Of note, is that this species is available during the dry season when water levels are lowest resulting in higher insect densities, this is interesting as it is also when no other insects species are being collected (Table 3). Thirdly, the novel consumption of ticks (Ixodidae) that are found on cattle is reported. Although the Waama do not rear cows themselves, the Fulani group (known locally as Peulh) - the major cattle herders in the region - often travel between pastures. The Waama visit the Fulani to collect the engorged ticks, or the Fulani purposely stop by the Waama villages in order for the Waama to free the cattle of the pests, illustrating an interesting form of mutually beneficial collaboration between ethnic groups around the practice of entomophagy and pest management. However, as ticks vector an array of human diseases there is need for more research on the health risks of using ticks as food. The use of *Anoplocnemis curvipes* (Fab.) (Coreidae) the giant coreid bug, for traditional medical purpose was also documented. This leaf-footed bug is traditionally mixed with spices, turned into a powder and then eaten to cure migraines. Although insects from the family Coreidae have been reported to be eaten in other countries (i.e., Zimbabwe, Mexico, China, Thailand and India - see Jongema 2013), their use in Benin appears to be exclusively medical. However, both the tick and the leaf footed bug are rarely consumed nowadays due to cultural changes in the use of livestock treatments and modern medicines. In the South, of particular interest is the consumption of several crop pests: such as *Locusta migratoria*, *Zonocerus variegatus*, *and R. phoenicis*. Although some grasshopper species are eaten in the North they were not reported to be pests of major concern. Instead the major concern in the North was a parasitic weed, *Striga hermonthica*, parasitising cereal crop plants mainly on marginal lands.

Gathering and preparation

Gathering traditions differ considerably between the North and the Central-South of Benin. In the Waama

Table 3 Seasonal distribution of the collected arthropodsy



settlements arthropods are collected and cooked mostly by children between the ages of 5 and 15 who practise this activity generally in groups. The activity is traditionally practised as a game where insects are considered a snack if successfully caught. This is the form in which entomophagy is transmitted from one generation to the next, allowing for this tradition to be maintained as an entertaining activity which is inherently part of growing up in the Waama communities visited. On the other hand, in the Southern communities, insect collection is an activity carried out by adults - men and women - and children. In the majority of cases in both the north and the south of Benin insect collection is for subsistence use only, particularly in times when harvests are poor. However, interestingly, amongst the Nagot (especially in Pobè) there are examples of middlemen that collect insects not for personal consumption but to sell in neighbouring Nigeria.

Insects are generally collected by hand, sometimes with the help of sticks to move vegetation or dig in burrows, although the collection of coleopteran larvae in the South is often carried out by adults with the help of a machete to cut through dead wood. Larvae of species from the subfamily Dynastinae are collected from rubbish heaps and the rotting trunks of palm trees. Those of *R. phoenicis* are collected in the stipe of palm trees from which the palm wine has already been extracted, with the collectors ascertaining their presence by listening for the clatter made by the mandibles of the insect. *Brachytrupes membranaceus* adults are often collected by children from their burrows. One exception to hand collection occurs in the case of the emergence of winged termites, which swarm in large numbers for short periods of time. In all three groups that consume termites, adults collect the insects at night using mass collection techniques involving large buckets of water under a light source. The collected termites are then dried, fried or made into sauces. Winged termites are also sold at rural and urban markets, which is the only case of commercial valorisation of insects in Benin.

For all other species, collections occur in the morning and evening when temperatures are lower and insects are slower and easier to catch. Insects are collected alive, and stored in empty plastic bottles or jars. They are brought to the family house where they are cooked with Shea nut butter and chilli or grilled on charcoal on the same day as collection. Interestingly, in the Waama communities, insects are shared amongst the group and are distributed to younger children who do not participate in the collection. In these communities, it is common for elder siblings to be responsible for looking after their younger siblings for large periods of the day. More recently, increasing school attendance among young children means that they have less time to pursue insect collecting. This may have repercussions on the preservation of entomophagy, in particular in the Waama communities where insect collection is carried out by children. As a result, nowadays this activity is only practised outside school times on Wednesdays, week-ends and holidays. Additionally, the consumption of insects appears to be linked to village life and Waama people who have moved away, usually to more urban environments or abroad, consume fewer or no insects and are not as likely to teach their children about insect gathering and eating.

Discussion

Practices of insect consumption in Benin

Comparing our data on edible insects to data on species eaten worldwide (Ramos-Elorduy 1997; Jongema 2013) and in Sub-Saharan Africa (van Huis 2003) we find that Orthoptera and Coleoptera are in the top four most

commonly consumed orders. Interestingly, Hymenoptera and Lepidoptera that are frequently recorded by all authors were not eaten in Benin. This is almost certainly due to cultural preferences of the groups in Benin as a number of species of Hymenoptera and Lepidoptera are eaten in other parts of Africa (Jongema 2013). In addition, a number of these species do occur in Benin (Appendix 3) but are not consumed. Across insect groups in general, only a fraction of the potential edible insects that occur in Benin are actually eaten (Appendix 3). There are, however, some families that are eaten in Benin as in other areas across the world (Appendix 4).

In the context of West Africa, entomophagy in Benin is more restricted than in neighbouring Burkina Faso, Niger and Nigeria where a variety of insects can be found in rural and urban markets (van Huis 2003; Banjo et al. 2006). Interestingly, the Nagot do collect insects to trade in Nigeria even though there is no internal market within Benin. In addition, our data suggest a very different insect diet between the North and the South of Benin. This is in part explained simply by the presence or absence of different species. For example, the consumption of the palm weevil is limited by the fact that oil palm trees occur only in Southern Benin. Ethnic preference also plays a large role in differences between groups. For example, the Waama would only eat the adults of Coleoptera because they believe the eating of larvae is unpleasant and do not consider it acceptable. This tradition also explains why larvae of Lepidoptera, such as *Cirina butyrospermi*, are not eaten by the Waama, despite being consumed in areas with similar climate and species availability in nearby Burkina Faso (N'Djolossè et al. 2012). Small scale differences in preference for adult or larvae have also been observed in other areas of Africa (Muafor et al. 2014).

Overall, the visited communities mostly consume insects that can be gathered directly in fields and high grasses around their villages, predominantly phytophagous species. This suggests that collection is to some degree reliant on convenience and access. Regarding crop management, of note is the consumption of several pests in the Southern communities. These include: *L. migratoria*, major, although a sporadic pest of cereal crops, *Z. variegatus*, a major pest of cassava crops in the Southern regions of Benin (Kekeunou et al. 2006), as well as the consumption of African palm weevil larvae (*R. phoenicis*), which is known to attack a variety of palms and can cause extensive damage (Sadakathulla 1991). These tropical pests are known to be more widely consumed (Bamaiyi and Aniesona 2012; van Itterbeeck and van Huis 2012) (Appendix 3 and 4). Interestingly, *R. phoenicis* is commonly eaten in Nigeria and Cameroon, where "semi-cultivation" of the larvae is practised by indigenous groups (van Itterbeeck and van Huis 2012).

In the literature, entomophagy has been shown as a potential means to help manage pests on agricultural crops (Cerritos and Cano-Santana 2008). An example of pest management through - or complemented by - entomophagy is that of eating grasshoppers, as occurs in many African countries where the sale of harvested and marketed grasshoppers may yield more revenue for farmers than millet (van Huis 2003). In the case of the Waama, however, although most of the insects consumed were potential pests - they are not considered as major pests. This is possibly due to the small scale mosaic structure of the local agriculture. In Southern Benin, where agriculture is more extensive and problems due to insect pests more prominent, insect consumption may have a beneficial effect on pest control. However, control is not the intended purpose of collection and is often just a by-product of entomophagy. The loss of local traditions in these communities is therefore unlikely to have major repercussions in terms of crop protection.

Looking within Benin, we find that different ethnic groups have distinct insect preferences. Only three species of insects are eaten by more than one group. In the South the main insect consumed across different localities are larvae of *Oryctes spp*. and *R. phoenicis*. In contrast, the Waama in the North consume a more varied assemblage of insects. A more diverse insect diet may be associated with the poor and unreliable productivity of agriculture in the region, which means that the North is more prone to repeated famines and problems of chronic malnutrition (Dr. Priuli, Hospital St Jean de Dieu, Tangiueta, Pers. Comm.). Under those circumstances, insects could be an important alternative source of food. Although their insect diet is diverse, the Waama avoid eating any larvae. This local aversion for the soft and usually most nutritious stage of the insect (van Huis 2003) reveals the presence of barriers of local traditions preferences being a hindrance for the commercial development of certain insect species across the country. However, a recent review on the nutritional value of a variety of edible insects (Rumpold and Schlüter 2013) showed that *Cybister*, *Brachytrupes* and *Hieroglyphus* species, which are all eaten by the Waama, could be important sources of proteins and high energy substrate (respectively 69, 35 and 36 %) and fats (respectively 5.5, 53 and 7 %), although more work on the nutritional value of species available in Benin is required. Particularly interesting would be to investigate the nutritional value of the large and soft bodied cricket, *G. sculpturatus*, as it is easy to collect and is highly appreciated by the Waama children. Also of note is the potential pharmacological toxicity of *Z. variegatus* secretions (Idowu and Idowu 1999); more research on the health risks of this species should be done with regard to nutrition.

Nevertheless, similarities exist across Benin, as well as being shared with other countries across Africa. One such example is termites. Termites have been part of the human diet since prehistoric times (van Huis 2003), with their sexual winged forms being the most popular today. Fried or dried termites contain 32–36 % proteins (van Huis 2003), they are also high in vitamins and iron (27 mg/100 g) (Banjo et al. 2006). The widespread practice of eating termites alongside their high nutritional value makes them a good starting point to develop entomophagy in the area. In Benin and neighbouring countries termite mounds also provide once per year highly appreciated fungi for human consumption (Sileshi et al. 2009). The Macrotermitinae cultivate edible mushrooms in the genus *Termitomyces* in the termitaria. Each year, these fungi produce a crop of large mushrooms, which are highly prized by people as a delicacy and are commercialised in Ghana. However, the limited seasonal availability of termites and their complex ecology make them impractical to rear. Interestingly, in East Africa, termite mounds are often owned and protected by individual families (van Huis 2003). In addition, a good understanding of how many termite mounds are in an area and sensible collection by avoiding the harvesting of the termite queens would help to avoid overexploitation and promote long-term management of the resource.

Perspectives on developing insect use in Benin

Currently in Benin, insects are unlikely to be consumed in adequate amounts or frequency to have an effect on the nutritional status of the child or the adult (Dr. Aouanou, Hospital St Jean de Dieu, Tanguieta, Pers. Comm.). Instead, there is evidence that consumption of insects is declining in some areas and is often lost when people move away from villages to urban areas. Therefore emphasising the importance of these cultural traditions, through documenting their current extent, and protecting these practices from being lost is vital if insects are going to play a role in food security in the future. In Benin, this is a particularly acute point as, at the moment, the market value for insects is very limited - the only example of the trading of insects being with groups from neighbouring Nigeria, or localised and seasonal trading of termites. In addition to preserving the tradition, increasing the understanding of the high nutritional value of insects within these communities may change attitudes towards entomophagy. Development of rearing methods for edible insects, rather than relying on natural harvesting, could also provide a continuous supply of insects. Both increased awareness of their value and increased availability could improve the integration of this nutritional resource into daily diets. Protecting and enhancing current practices would also provide a basis for valorising insects as an agricultural product in the long term.

Recently, a number of edible insects have begun to be farmed for human consumption - including the house cricket, the palm weevil (*R. phoenicis*), the giant water bug (*Lethocerus indicus*) in Thailand and water beetles in China (Hanboonsong et al. 2013; van Huis 2013). However, practical and cultural issues should be given close attention in order for insect rearing to be successful. A community specific approach would increase chances of success. In Benin several points should be considered before trialling captive rearing projects. First, it is imperative that any facilities are affordable or subsidised to allow projects to gain initial local support. Second, as ethnic preferences vary between groups it is important to trial farming with species that are in line with local traditions. Preferences are likely to have a large effect on how well any product could be adopted, promoted and eventually marketed (Bauserman et al. 2013). Another consideration is nutritional quality, as protein and micronutrient content can vary significantly among insect species (Banjo et al. 2006; Rumpold and Schlüter 2013). Taking into account these considerations, it appears different mini-livestock productions focussed on particular communities could be feasibly trialled in Benin. In the South it would be possible to rear the palm weevil and/or rhinoceros beetle larvae. These larvae are very high in protein and require low inputs for the quantity and quality of nutrition provided (FAO 2010; Ekpo 2011). Lessons can be learnt from Indonesia where the Asiatic palm weevil (*Rhynchophorus vulneratus*) is reared for eating using decaying palm trunks (FAO 2010). On the other hand, in the North of Benin, Orthoptera appear better suited due to the strong local distaste for eating insect larvae. We suggest that three species of grasshoppers (*H. africanus*, *A. ruficornis* and *O. turbida*), eaten by the Waama, could be potentially considered as local species for small scale farming. Alternatively, due to mole crickets being accepted as food, it may be possible to farm a cosmopolitan species such as the house cricket (*Acheta domesticus*), for which there is considerable information on rearing (Hanboonsong et al. 2013). Neighbouring countries, where small scale farming of orthopterans is starting to be developed (Project ICCO: Edible insect breeding in Kenya), could provide additional support. Small scale rearing of *Cybister* sp. could also be considered based upon current facilities in China and Thailand (van Huis 2013).

Fortunately, other countries, for example neighbouring Burkina Faso, Niger and Cameroon, have proved that the commercialisation of edible insects in Africa is possible and can be remunerative (Dr. Razack, IITA, Pers. Comm.). These can provide local examples to model

projects on as well as offering potential markets for insect production in the long term. Promoting cultural exchange, however, is essential for the regional development and trade of insects. Following the example of Cambodia and Thailand where programmes and agreements have been set up to promote insect trade across the two countries, there has recently been a call for a West African platform to be set up to develop entomophagy in the region (Dr. Rousseau, IITA, Pers. Comm.). More dependable supplies provided by insect farming could contribute to tackling issues of both malnutrition and agricultural diversification in Benin. Nonetheless, recognition and promotion of traditional insect gathering on top of any captive rearing projects is important and the development of rearing facilities should not necessarily replace, but rather enhance local traditions. Unfortunately, while Benin faces severe issues of poverty and malnutrition, currently insects remain an undervalued and underused resource to address these problems. There is potential in using local traditions to tackle regional and national issues. However, as traditions give way to modern lifestyles, there is an urgent need to capitalise on local knowledge before it is lost. Changing national perceptions of entomophagy is fundamental to protecting and promoting entomophagy in Benin. Cultural differences in entomophagy between different ethnic groups imply that targeted programmes of promotion should be considered in Benin.

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Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

Authors contributions Conceived and designed the study LR, RLV, MV. Performed the fieldwork LR, RLV, MV, CM. Wrote the paper, LR, RLV, MV, GG.

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Mariangela Veronesi I work in the development sector and specialise in environmental planning. This came after completing a BSc in Economics and International Development at the University of Bath followed by an MSc in Environmental and Sustainable Development at the Development Planning Unit, UCL. In particular, I am interested in self-managed development, local empowerment and participatory research and planning, especially concerning environmental issues. Most recently I worked in the running of the World Habitat Awards with the Building and Social Housing Foundation. As part of Bugs for Life, I follow the social and development aspects of the project, along with coordinating fundraising activities.

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