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EDIBLE NON-CRUSTACEAN ARTHROPODS IN RURAL COMMUNITIES OF MADAGASCAR

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Entomophagy, the practice of eating insects, is not new in many countries, including Madagascar, where insects have long been part of culinary traditions. Promoting this practice would help in enhancing food security as insects are nutritious and affordable for the majority of the population. Because eating insects is also associated with rural life, we conducted a survey in rural communities of Madagascar from April to June 2013. Diversity of edible, non-crustacean arthropods was assessed for each site using the number of times names of arthropods consumed were mentioned by each household. Approximately 65 morpho-species from seven orders of insects, including Hemiptera, Coleoptera, Lepidoptera, Orthoptera, Hymenoptera, Odonata, and Mantodea, and two orders of arachnids, including Araneae and Ixodida, were recorded as the most frequently consumed arthropods during the survey. Preference rankings differed among sites, possibly depending on the availability of the edible species; information on seasonal availability was also recorded from the informants. When comparing factors influencing food security in rural areas, most of the edible species were found between October and March, a time associated with the lean season and elevated food prices. This pattern demonstrates the importance of entomophagy in food security as Malagasy farmers rely heavily on their subsistence crops for their living. Rearing selected edible insects at a marketable level, combined with other insect-based activities such as sericulture, would further improve food security. Promoting the importance of ethnoentomology would be ultimately leading to more effective sustainability of edible insects and conservation of forests in Madagascar.

Keywords: *entomophagy, insect, Malagasy, food security, conservation*

With the rapid growth of the global human population and threats of insufficient food resources for the future, entomophagy, the practice of eating insects, has been long suggested as a component of strategies to improve food security (Gahukar 2011; Huis et al. 2013; Meyer-Rochow 1975; Ramos-Elorduy 1990). Insects are nutritious food, mainly because of their high content of proteins, fats and minerals (Barsics et al. 2013; Huis 2003; Malaisse 2005; Ramos-Elorduy 1997; Yhoung-aree 2010). They are also affordable, because many species can be gathered using low-technology tools and because their price in the marketplace is generally not high relative to other protein sources. Entomophagy is not a new practice, particularly in Asia, Africa, the Americas, and Australia, where people have long consumed insects and other arthropods as they do any other kinds of meat, although beef, pork, and poultry are now considered conventional foods in westernized societies.

We focused our study on entomophagy in Madagascar, an island off the southeast coast of Africa. Its inhabitants are the Malagasy people, an admixed population with sub-Saharan African and Southeast Asian ancestry (Hurles et al. 2005; Tofanelli et al. 2009), thus offering blends of cultures that embrace

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entomophagy. Fried locusts and grasshoppers as well as roasted silkworm pupae have been known as delicacies on the island for over 75 years (Bodenheimer 1951; Decary 1937). That Queen Ranavalona II (1829–1883) kept a group of women only to gather locusts, distinct from hunters and fishermen (Camboué 1886), illustrates the importance of entomophagy for Malagasy people, at least in the past.

Entomophagy as a dietary practice is associated with rural life in Madagascar, as edible insects are mostly gathered in rice fields or forests but not reared, except for certain species of silkworm used primarily for sericulture. However, many farmers currently experience difficulties in terms of drought, property right disputes, and antiquated agriculture practices that lower crop yields (Badjeck et al. 2013). Poverty has lingered in many parts of the country, where the poorest farmers are not able to consume as much meat as they would like but instead subsist on rice as the staple food, along with some vegetables; thus, lack of diversity of food and shortages of animal proteins and dairy products are the main problems they face in terms of nutrition (Badjeck et al. 2013).

In Madagascar, about 32 edible species from different orders are recorded in the published literature (Jongema 2012). This richness in edible species is explained in part by the ancestral origin of Malagasy people involving blends of cultures that embrace entomophagy. Also, Madagascar is known for its exceptional tropical natural biodiversity (Myers et al. 2000), characterized by the presence of different species in different types of ecosystems. A decrease in a cultural emphasis on entomophagy (Gade 1985), an inability to gather sufficient quantities to meet local community needs, or unavailability of edible species due to loss of habitats from slash-and-burn agriculture and overexploitation of forests are all possible reasons that edible insects have not been widely utilized as food despite their nutritional quality. These different possibilities led us to examine entomophagy and its current status more closely by updating information about the diversity of edible insects and other non-crustacean arthropods in Madagascar.

Our study aimed to record insects and other non-crustacean arthropods that Malagasy people in a particular region consume and to assess whether edible species diversity and the mode of consumption vary among regions, in view of the fact that each region possesses its unique ecosystems, local cultures, and economic activities. Seasonal availability of the insects was also recorded in order to determine whether entomophagy is important in the yearly diet of the people in the studied regions. Information about entomophagy obtained from this study can be useful for designing strategies to utilize edible insects for future development projects, such as promoting certain species as food to enhance protein nutrition to improve food security and community-based conservation in Madagascar.

Materials and Methods

A survey of local people was conducted in order to study the importance and the diversity of non-crustacean edible arthropods in Madagascar. Malagasy was the language of communication during the survey as Malagasy people share the same language, with several similar dialects, spoken by approximately 18 ethnic groups. Although each ethnic group has its particular traditions, many customs

and ways of life are shared, such as using rice as the main staple food accompanied with zebu meat for different celebrations. We restricted our study to rural communities, as more than half (67.4%) of Malagasy people live in rural areas (Food and Agriculture Organization 2013a).

An average of 26 heads of households, ranging between 18 and 64 years old, either the father or the mother, were interviewed door-to-door via a zigzag pattern, a modified method from Razafimanahaka et al. (2012). We interviewed only heads of households because we assumed that family members traditionally share the same daily meals, individual diet preference among the members notwithstanding. Thus, investigating heads of households would be equivalent to seven-times more informants, implying a total of approximately 130 informants per site, because the number of children for each Malagasy mother was estimated at an average of 4.8 in 2009 (Institut National de la Statistique and Inner City Fund International 2010). To evaluate the demographic size of each site, we counted the number of houses, which is equivalent to the number of households in our study as it was difficult to obtain the exact population size in a particular small town or village. One exception was Maroantsetra, where the exact number of inhabitants for each subsite was recorded from local organizations of development.

We usually started the survey early in the morning before people left the village for work, or in the late evening when they returned home. Interviews were undertaken in person, using a questionnaire that we filled out to avoid any discomfort or impression of test-taking. The informants were literate (mostly at the elementary level) as they had to read and sign a consent form for the survey. The questionnaire solicited information about insects consumed by members of the household, including names, stages, modes of collection and preparation, and availability during the year. All questions in the questionnaire were answered. If available, colored photographs of the main species listed in Jongema (2012) were shown to interviewees to facilitate description of the species and to record at least the family or the order of the insect consumed. These photographs proved useful in that only some specimens mentioned by the informants could be collected by any members of the family or by us and our field assistants accompanied by a local villager. We identified the captured arthropods through keys or by comparison with specimens in the insect collection of the botanical and zoological park of Tsimbazaza (PBZT). Scientific names were confirmed at the website of the Global Biodiversity Information Society (2014). The relative importance of the non-crustacean edible arthropods was evaluated by quantifying the number of times their names were mentioned by the informants. Data were analyzed using descriptive statistics (SPSS 22.0).

All sites were towns or villages located in the general vicinity of forests and sericulture centers, with a range of variation in ecosystem characteristics, cultural values and human activities. Sericultural activities were especially taken into consideration because they can be combined with remunerable activities associated with entomophagy (Schabel 2006). Extensive agriculture for subsistence, mainly growing rice and raising zebu cattle, were the major activities in all sites. Other crops such as cassava, corn, and sweet potato were also grown in most of the regions.

The study sites, illustrated by a map created by using ArcGIS® software and a map of vegetation from Dupuy and Moat (1996) detailed in Randrianandrasana et al. (2014), were located in the highlands of Madagascar, including Ambatofinandrahana and Anjà, and the littoral areas, including Mahabo, Maroantsetra, and Vatomandry (Figure 1). Each site was composed of subsites, ranging from two to five villages. In total, heads of 437 households were interviewed in 17 villages or towns in the five sites. Fewer than 1% of the heads of households denied our request for an interview because they insisted on payment in exchange for information. To facilitate localization of each site, Antananarivo, the capital of Madagascar, which is situated in the center of the island, was chosen as a point of reference.

The two sites in the highlands, Ambatofinandrahana and Anjà, are both in the province of Fianarantsoa, which is the region populated by the Betsileo ethnic group. Ambatofinandrahana is located 333 km south Antananarivo and 67 km from Ivato, an intersection between National Road No. 7 that winds south to the Anjà site and the National Road No. 35 that leads west to the Mahabo Morondava site. The survey in Ambatofinandrahana was conducted in three subsites, interviewing 30 heads of households each: Ambatofinandrahana Town (north part of the town, close to crop fields; 692 houses), Ambatomenaloha (47 houses) and Tetikanana (152 houses). Ambatofinandrahana is one of the regions in Madagascar where endemic fire-resistant forests are found. They are dominated by *Uapaca bojeri* Baill. (Phyllanthaceae) trees, known locally as *tapia*, and hence they are called *tapia* forests. Because the wild silkworm, known as *landibe*, commonly used for traditional sericulture in the country, *Borocera cajani* Vincent (Lasiocampidae), lives on *tapia* trees, the site is well known for its traditional silk production (Paulian 1953; Rakotondrasoa et al. 2012). Mining also constitutes one of the main activities in Ambatofinandrahana, where marble, granite and various minerals form its rocky soils (Praszkier 2010).

The other Betsileo site, Anjà, is located along National Road No. 7, at 468 km south of Antananarivo and 12 km south of Ambalavao, another important sericultural center in Madagascar. Five villages were chosen for the survey, namely the two twin villages Ambalalova-Bevolotara (92 houses) and Mandrabary-Amontavoloina (90 houses), and Ankadidisa (95 houses), where 17, 18, and 38 heads of households were interviewed, respectively. They are all situated on the borders or close to the granite outcrops covered by rupicolous vegetation, between which are found forest relicts. Ring-tailed lemurs, *Lemur catta* Linnaeus (Lemuridae), inhabit these unique forest remnants. Also, the bedrock itself offers a spectacular historical scene because of the tafonies, which are caves, high up on the slopes of the rocks, used as the Betsileo king's sacred tombs in the past or as places of refuge during periods of persecution. Ecotourism has been a recent source of income for the local people, who were previously mainly subsistence farmers (Nyamulisa 2012; United Nations Development Programme 2013).

Three sites were visited in littoral parts of Madagascar. Mahabo is located 45 km from Morondava and 649 km southwest of Antananarivo, near the littoral west in the Menabe region. Three villages, all along National Road No. 35, were visited: Bezezika (337 houses), Manamby (360 houses) and Mihary (219 houses), where 23, 21, and 22 heads of households were interviewed, respectively. As

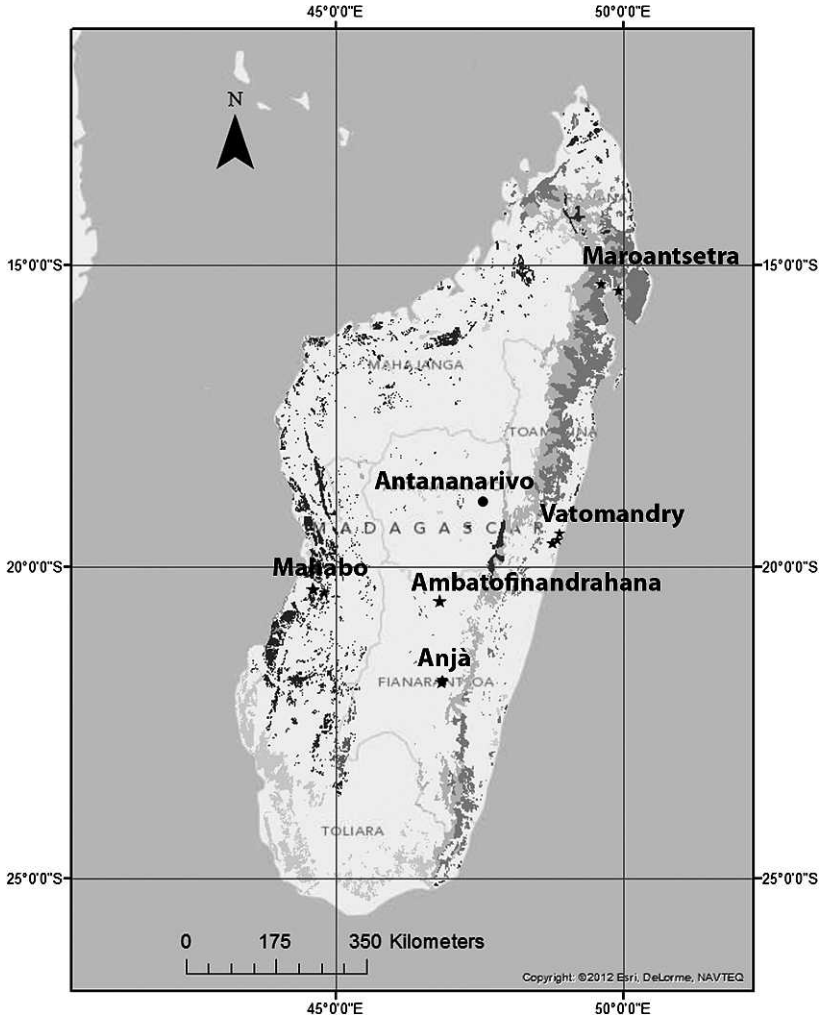

Figure 1. Study sites where a survey of entomophagy was conducted in Madagascar from March to June 2013. Antananarivo is the distance point of reference. Base map from World Light Gray through ArcGIS® software; primary vegetation map by Dupuy and Moat (1996). Copyright by Esri, Delorme, Navteq, and RBG Kew.

Mahabo lies along fluvial plains, agriculture is very important, especially rice and cotton, along with fishing and zebu cattle ranching (Rakotoarivelo 1970). Also, ecotourism and wood logging are important to the local economy (Delaporte et al. 1996), due to proximity to the Kirindy Reserve and its spectacular avenue of baobab trees. No silk production activities were observed in the study sites, although species of wild silkworms were noticed in the neighboring forests (Randrianandrasana et al. 2014). The Sakalava are the majority ethnic group of the Menabe region, but some other ethnic groups from other parts of the country, including the Antaisaka, Betsileo, Antandroy, and Korao are found in Mahabo (Rakotoarivelo 1970). In the littoral east, where the

Betsimisaraka are the majority ethnic group, two sites, Maroantsetra and Vatomandry, were visited. Apart from rice and subsistence crops, cash crops such as vanilla, coffee, and clove are grown in the region. The first site visited was Maroantsetra, where most of the large remaining dense rainforests in Madagascar are found. It is located in the northeast of the country, 451 km from Antananarivo. Two villages were chosen as subsites: 1) Ambodivoangy (1301 inhabitants, Maminirina Randrianandrasana, pers. comm.), located along the Antainambalana River on the border of the Makira Reserve, 21 km northwest of Maroantsetra Town, where 24 heads of households were interviewed; and 2) Mahalevona (9591 inhabitants, Maminirina Randrianandrasana, pers. comm.), on the border of Masoala National Park, 19 km east of Maroantsetra Town, where 38 heads of households were interviewed. These two are recent sites of novel sericulture using *Antherina suraka* (Boisduval) (Saturniidae), producing silk that has not been used until very recently in the region (Craig 2007). Apart from agriculture, forestry, ecotourism, and logging are the main activities in Maroantsetra. The second site, Vatomandry, is situated on the path of the Pangalanes Canal and National Road No. 11, 271 km northeast of Antananarivo. Four sites—Ambalamangahazo (280 houses), Antanambao (400 houses), Ampaho (444 houses), and Sahabe (102 houses)—were visited, where 21, 22, 43, and 16 heads of households were interviewed, respectively. No major silk-producing activities were observed in that region. Apart from agriculture, Vatomandry has become one of the closest seaside resorts for the inhabitants of Antananarivo since the main road was repaired recently (Integrated Regional Information Network 2006).

Results and Discussion

Our survey, conducted from March to June 2013 in five study sites in the highlands and littoral parts of Madagascar showed that Malagasy people in rural areas still consume insects as did older generations. From an average of 26 heads of households interviewed for each subsite, our current studies revealed 2,512 arthropods identified to 65 morpho-species, differentiated by their common names, belonging to seven orders of insects and two orders of arachnids. Among these 65 morpho-species, 53 were later identified to species, a greater number than the 32 species of insects recorded as dietary items in Madagascar by Jongema (2012). This finding cannot be regarded as evidence of greater consumption of insects by current informants in comparison with older generations because of uncertainties over identifications—one common name can be used for two different species, for example, or vice-versa, two common names for one species.

Entomophagy in Madagascar Compared to the World

Although results from the five sites in this study could not be considered as representative of an entomophagy trend for the entire country, we compared the number of edible species consumed in Madagascar from our survey with those compiled by Jongema (2012) across the globe, and in two biogeographic realms where the Malagasy ancestors originated, the Indo-Malayan and Afrotropical zones (Table 1). In this comparative study, we used only the 53 identified species instead of the 65 morpho-species recorded in order to obtain uniformity of data

Table 1. Comparison of edible non-crustacean arthropod species (values in percentage).

Order	World	Indo-Malaya	Afrotropic	Madagascar
Blattodea	5	6	8	0
Coleoptera	***31***	***48***	***16***	***36***
Diptera	2	1	1	0
Hemiptera	10	***11***	9	***23***
Hymenoptera	***14***	7	7	6
Lepidoptera	***18***	4	***34***	***17***
Odonata	3	6	1	4
Orthoptera	13	***16***	***24***	9
Others[a]	4	2	1	6

Note: Bold italicized numbers represent the three most frequently consumed groups per zone.
[a] Orders of arthropods with fewer than 2 % edible species each.

recording in our study and the other regions of the world. We noticed that Coleoptera were most widely consumed in the world (31%) and in the Indo-Malayan region (48%) as in Madagascar (36%), although beetles were less frequently consumed in sub-Saharan Africa (third most widely consumed at 16%). Insects in the order Hemiptera comprised the second most frequently consumed group in Madagascar (23%) but species in this order were not as important in terms of consumption in the world at large (10%) and in either the Indo-Malayan region (11%) or sub-Saharan Africa (9%). Lepidoptera comprised species that were the most frequently consumed in sub-Saharan Africa (34%) but ranked second after Coleoptera worldwide (18% [third in Madagascar 17%]). This order ranked only

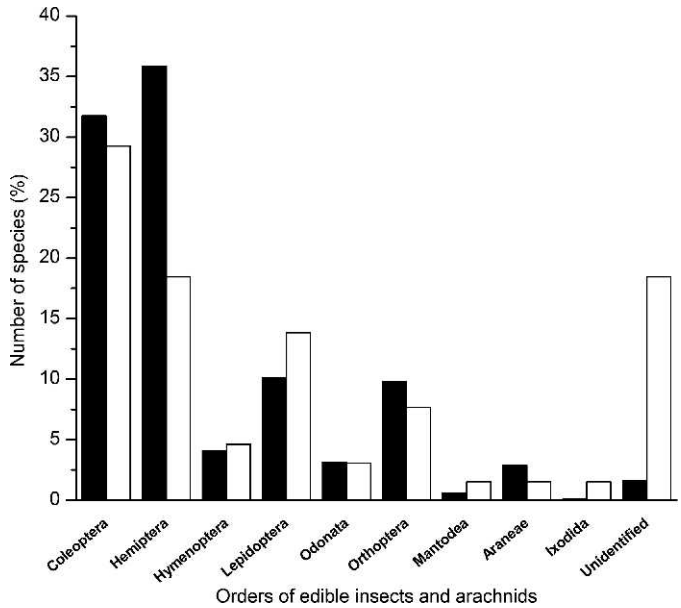

Figure 2. Insects and arachnids in different orders consumed by local people in five sites, Ambatofinandrahana, Anjà, Mahabo, Maroantsetra, and Vatomandry, in Madagascar. Black: number of times common names mentioned by informants; white: species mentioned.

Table 2. Orders of insects and arachnids consumed by local people in five sites in Madagascar.

Site[a]	Coleoptera (% mentioned)	Hemiptera (% mentioned)	Hymenoptera (% mentioned)	Lepidoptera (% mentioned)	Mantodea (% mentioned)	Odonata (% mentioned)	Orthoptera (% mentioned)	Araneae[b] (% mentioned)	Ixodida[b] (% mentioned)	Undefined (% mentioned)
Ambatofinandrahana 3 subsites, n=90, a=410	28.29	7.56	0.00	32.44	0.00	11.71	19.02	0.00	0.00	0.98
Anjà 5 subsites, n=117, a=1010	24.26	45.45	0.00	7.23	1.49	2.18	11.09	7.13	0.00	1.19
Mahabo 3 subsites, n=66, a=435	41.15	38.39	0.00	7.59	0.00	0.92	8.51	0.00	0.69	2.76
Maroantsetra 2 subsites, n=62, a=305	40.00	44.92	0.00	5.25	0.00	1.64	4.26	0.00	0.00	3.93
Vatomandry 4 subsites, n=102, a=352	38.64	30.11	29.26	0.00	0.00	0.00	1.99	0.00	0.00	0.00
Grand total 17 subsites, n=437, a=2512	31.77	35.83	4.10	10.15	0.60	3.14	9.83	2.87	0.12	1.59

[a] n=number of heads of households interviewed; a=number of responses
[b] Non-insect Arthropoda in the Class Arachnida.

Figure 3. The Malagasy golden orb-weaver, *Nephila inaurata* (Nephilidae), caught on its web on one of the walls of a house in Anjà. Photo by Maminirina Randrianandrasana.

seventh most consumed in the Indo-Malayan region (4%). Orthoptera, although second most frequently consumed in the Afrotropical region (24%) and in the Indo-Malayan region (16%), was ranked fourth worldwide (10%) and in Madagascar (9%). Although insects in the order Hymenoptera (14%) were the third most frequently consumed worldwide, they were less important than the previously mentioned orders in the Indo-Malayan region (7%) and sub-Saharan Africa (5%), including Madagascar (4%). Termites (belonging to Blattodea), consumed in both sub-Saharan Africa (8%) and Indo-Malaya (3% as separated from other groups in Blattodea), were surprisingly not regarded as edible insects despite their abundance in the south and west of the island; rather, they were used for feeding poultry and domesticated pheasants (Decary 1950). This comparison showed that the Malagasy people in our study preferred arthropods in the same groups as those consumed worldwide although they eat more species of Hemiptera than Hymenoptera. The entomophagy trend of Malagasy people also reflected their admixed ancestors' tastes, as they preferred Lepidoptera and Coleoptera as do other people respectively in Afrotropical and Indo-Malayan regions.

By recording the number of times each common name was mentioned by the informants, rather than the species of arthropods, we could improve the accuracy of rankings of preferred edible arthropods. As an example, edible species in Hemiptera were found more widely consumed than Coleoptera (Figure 2), the two most important edible insect orders in the five sites studied in Madagascar (Table 2). The third most frequently consumed insects were species in the order Lepidoptera. The order ranked second in Ambatofinandrahana and third in

Table 3. Five most frequently consumed insects in five sites in Madagascar.

Site/insect	Number of times mentioned
Ambatofinandrahana	
Zana-dandy (silkworm pupae, Lepidoptera)	83
Valala (locusts or grasshoppers, Orthoptera)	78
Kijaja (saturniid larvae, Lepidoptera)	50
Angidindrano (dragonfly nymphs, Odonata)	48
Tsikovoka (adult diving beetles, Coleoptera)	42
Anjà	
Angala (giant water bugs or water scorpions, Hemiptera)	211
Bora (cicadas or spittle bugs, Hemiptera)	111
Valala (locusts or grasshoppers, Orthoptera)	103
Voangory (adult melolonthinae beetles, Coleoptera)	101
Tsikovoka (adult diving beetles, Coleoptera)	94
Mahabo	
Sakondry (fulgorid planthoppers, Hemiptera)	51
Tsikovoka (adult diving beetles, Coleoptera)	51
Bora (cicadas or spittle bugs, Hemiptera)	49
Angala (giant water bugs or water scorpions, Hemiptera)	48
Bongy (larvae of Scarabaeidae/Cerambycidae/Lucanidae, Coleoptera)	46
Maroantsetra	
Bora (cicadas or spittle bugs, Hemiptera)	53
Sakondry (fulgorid planthoppers, Hemiptera)	51
Voatandroka (adults and larvae of Scarabaeidae Dynastinae, Coleoptera)	50
Angala (giant water bugs or water scorpions, Hemiptera)	33
Bongy (larvae of Scarabaeidae/Cerambycidae/Lucanidae, Coleoptera)	30
Vatomandry	
Sakondry (fulgorid planthoppers, Hemiptera)	77
Fanenitra (vespid wasps, Hymenoptera)	68
Bongy (larvae of Scarabaeidae/Cerambycidae/Lucanidae, Coleoptera)	54
Voangory (adult Melolonthinae beetles, Coleoptera)	50
Tantely kinjany (larvae of honey bee, Hymenoptera)	35

Note: Evaluation of preference based on the number of times the name of the insect was mentioned by the informants.

Maroantsetra, two regions known for wild sericulture. The pupae of *B. cajani* were commonly consumed in Ambatofinandrahana. One of the reasons stated by the informants who do not consume silkworm pupae in this region was that they did not want to risk ruining their sericultural activities. In Maroantsetra, the sites were close to dense forests where wild pupae of *Hypsoides* spp. (Notodontidae) could be easily collected (Ranaivosolo and Randrianandrasana 2008).

Species of Orthoptera, the fourth most frequently consumed group, were mentioned mainly by informants in Ambatofinandrahana, Anjà, and Mahabo, where invasions of locusts (Acrididae), *Locusta migratoria capito* Saussure and *Nomadacris septemfasciata* Audinet-Serville, periodically occur (Office for the Coordination of Humanitarian Affairs 2013). Technically, immature locusts are generally controlled with pesticides when their populations outbreak to protect crops, but people consumed them when they were not treated with pesticides.

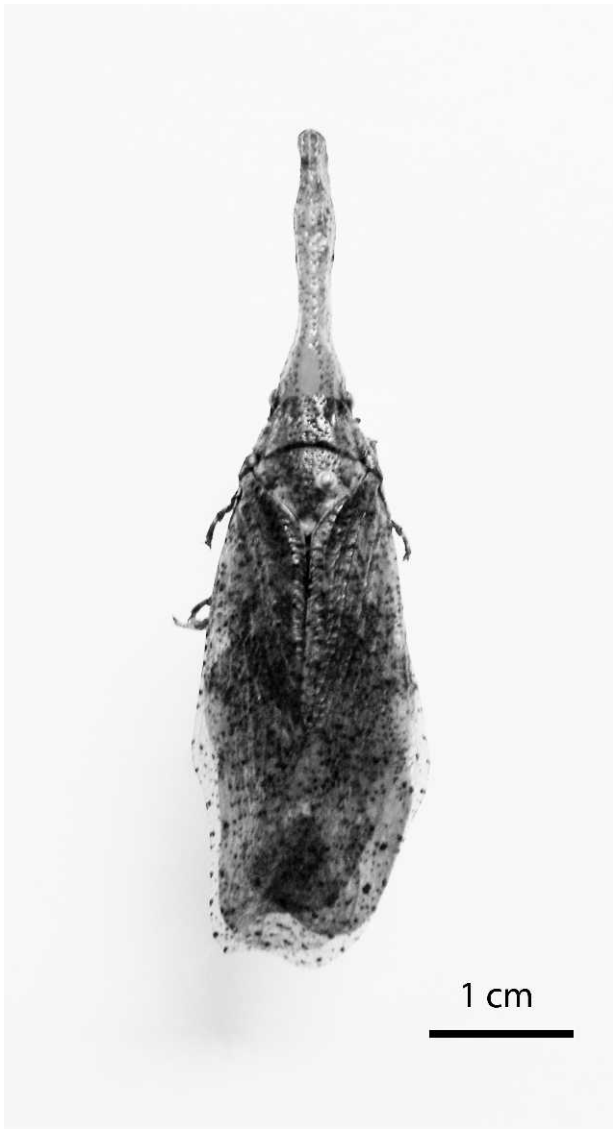

Figure 4. *Sakondry*, *Zanna madagascariensis* (Fulgoridae), consumed in Anjà. Photo by Maminirina Randrianandrasana.

That was the case for 2012 and the first half of 2013, as the favorable climate conditions and political instability, starting in 2009, impeded locust control efforts (Food and Agriculture Organization 2013b). The locusts were not really known as edible insects in the northeastern part of Madagascar, such as Vatomandry and Maroantsetra, where there was no infestation. Only informants who have travelled to already-infested neighboring areas such as Mandritsara and the southern part of the island, had tried them fried or cooked by local people.

Praying mantises (Order Mantodea), called *famakiloha* or *tsipeko* and including *Paramantis viridis* Saussure (Mantidae), were consumed when

Figure 5. *Bongy*, a rhinoceros beetle larva (Scarabaeidae, Dynastinae) consumed in Mahabo Morondava. Photo by Maminirina Randrianandrasana.

encountered by only a few people in Anjà. The only Hymenoptera species consumed in larval and pupal stages were recorded in Vatomandry and included honey bees and wasps. Thus, Hymenoptera species are still consumed in restricted areas of Madagascar, although they were previously regarded as no longer part of the Malagasy diet (Grandidier and Grandidier 1903–1920).

Orb-weaving spiders (Araneae), mainly *Nephila inaurata* (Walckenaer) (Nephilidae), the Malagasy golden orb-weaver (Figure 3), were reported to be consumed only in Anjà, not in Ambatofinandrahana, although both sites are in the highland region where orb-weavers were previously reported to be consumed. Few people encountered during fieldwork in other areas of the highlands confirmed that they had consumed *N. inaurata* at least once in their lives, such as during their childhood, or at least used their strong web to trap beetles for consumption. Other orb-weavers found in rice fields that were not identified were also consumed by two heads of households. Consumption of ticks (Ixodida, Arachnida) called *kongona* or *kongon'omby*, was also recorded from three households in Mahabo but nowhere else in our study. They were not described as constituting a real meal but rather were picked up from the skins of zebus and consumed while cattle-herders were bored. The handful of common names mentioned by the informants needed further investigation and were classified as "Undefined" because we could not collect specimens for identification and the description was not precise enough to classify them even to the level of order.

Ranks of most preferred edible insects varied according to the regions where the informants lived (Table 3). The fulgorid planthoppers, *sakondry*, were

Table 4. Specimens of edible Coleoptera recorded in Madagascar from January to June 2013 and December 2013.

Scientific name	Family	Common name	Location	Stage consumed
Aquatic beetles				
Cybister cinctus Sharp	Dytiscidae	*Voatsingovoka*	Vatomandry	Adult
Cybister desjardinsii Aubé	Dytiscidae	*Voatsingovoka*	Vatomandry	Adult
Cybister operosus Sharp	Dytiscidae	*Tsikovoka*	Unspecified	Adult
Cybister tripunctatus (Olivier)	Dytiscidae	*Tsimangovo*	Mahabo	Adult
Cybister vulneratus Klug	Dytiscidae	*Tsikobo, tsikoboka, tsikobono*	Maroantsetra	Adult
Cybister sp.	Dytiscidae	*Tsikovok*a	Unspecified	Adult
Unidentified	Dytiscidae	*Kaity*	Anjà	Adult
Sternolophus sp.	Hydrophilidae	*Tsimangovo, tsikobo, tsikoboka, tsikobono*	Mahabo, Maroantsetra	Adult
Unidentified	Dytiscidae, Hydrophilidae	*Kibehara, tsibehara*	Mahabo	Adult
Unidentified	Dytiscidae, Hydrophilidae	*Ikalamainty*	Anjà??	Adult
Unidentified	Dytiscidae, Hydrophilidae	*Fanenin-drano, fangorinana*	Ambatofinan-drahana	Larva and pupa
Dineutes sp.	Gyrinidae	*Fandiorano*	Vatomandry	Adult
Terrestrial beetles				
Scarites sp.[a]	Carabidae	*Sahobaka*	Anjà, Mahabo, Maroantsetra	Larva and pupa
Batocera rufomaculata (Degeer)	Cerambycidae, Lamiinae	*Ombilahin-janahary*	Vatomandry	Larva and pupa
Unidentified	Cerambycidae, Lamiinae	*Ombilahin-janahary*	Vatomandry	Larva and pupa
Cladognathus serricornis Latreille[a]	Lucanidae	*Sahobaka*	Anjà, Mahabo, Maroantsetra	Larva and pupa
Oryctes boas (Fabricius)	Scarabaeidae, Dynastinae	*Voatandroka*	Mahabo	Larva, pupa and adult
Oryctes gigas Castelnau	Scarabaeidae Dynastinae	*Voatandroka*	Vatomandry	Larva, pupa and adult
Oryctes pyrrhus Burmeister	Scarabaeidae Dynastinae	*Voatandroka*	Mahabo	Larva, pupa and adult
Unidentified	Scarabaeidae Dynastinae	*Voatandroka*	Maroantsetra	Adult
Unidentified	Scarabaeidae Dynastinae	*Lafa bitay*	Maroantsetra	Larva and pupa
Enaria limbalis Fairmaire	Scarabaeidae Melolonthinae	*Voangaratra*	Vatomandry	Adult
Hoplochelus marginalis (Fairmaire)	Scarabaeidae Melolonthinae	*Voangory fotsy vody*	Ambatofinan-drahana, Anjà	Adult
Hoplochelus spp.	Scarabaeidae Melolonthinae	*Voangaratra*	Vatomandry	Adult

Table 4. Continued.

Scientific name	Family	Common name	Location	Stage consumed
Proagosternus sp.[a]	Scarabaeidae Melolonthinae	*Voangory be/ tsikondry*	Mahabo, Maroantsetra	Larva, pupa and adult
Tricholespis sp.[a]	Scarabaeidae Melolonthinae	*Voangory be/ tsikondry*	Mahabo, Maroantsetra	Larva, pupa and adult
Unidentified	Scarabaeidae Melolonthinae	*Voangory mavo*	Anjà	Adult
Unidentified	Scarabaeidae/ Cerambycidae/ Lucanidae and others	*Badro*	Ambatofinandrahana	Larva and pupa (underground)
Unidentified	Scarabaeidae/ Cerambycidae/ Lucanidae and others	*Bongy, bongy tany, bongy hazo, mandrilava*	Ambatofinandrahana, Anjà, Mahabo	Larva and pupa
Unidentified	Scarabaeidae/ Cerambycidae/ Lucanidae and others	*Lafa, lafa fohy, lafa kakazo, lafa ravinala, lafa sakaiva*	Maroantsetra	Larva and pupa
Unidentified	Scarabaeidae/ Cerambycidae/ Lucanidae and others	*Oli-bonga*	Ambatofinandrahana	Larva and pupa
Unidentified	Unidentified	*Kiamboamboa*	Ambatofinandrahana	Larva and pupa
Unidentified	Unidentified	*Andraitry jirofo*	Maroantsetra	Unidentified
Unidentified	Unidentified	*Fanito rafia, Tsingetretry*	Maroantsetra	Unidentified
Unidentified	Unidentified	*Tsivatravatra*	Anjà	Adult
Unidentified	Unidentified	*Tsivoangòna*	Vatomandry?	Adult
Unidentified	Unidentified	*Vasatra*	Vatomandry	Larva
Unidentified	Unidentified	*Voangory ajabo*	Anjà	Adult
Unidentified	Unidentified	*Voangory akoho*	Anjà	Adult
Unidentified	Unidentified	*Voangory amerikanina*	Anjà	Adult
Unidentified	Unidentified	*Voangory atsatsa*	Anjà	Adult
Unidentified	Unidentified	*Raplikely*	Anjà	Adult
Unidentified	Unidentified	*Voangory baovelo*	Anjà	Adult
Unidentified	Unidentified	*Voangory peratsy, voaperatse*	Anjà, Mahabo	Adult

[a] Scientific name associated with the common name according to Decary 1937.

especially preferred in the littoral areas such as Mahabo, where *Zanna tenebrosa* (Fabricius) were collected, Vatomandry, where *Zanna madagascariensis* Signoret were collected, and Maroantsetra. The latter species was also consumed in Anjà, where it was ranked as the tenth most preferred insect at the site (Figure 4).

Edible Species

Presented here is the information obtained during our study on edible insect species arranged by order, with their common names and/or scientific names, their edible stages of development, their habitat characteristics (aquatic or terrestrial) and the informant's preference. Their general mode of consumption and their seasonal availability are also presented.

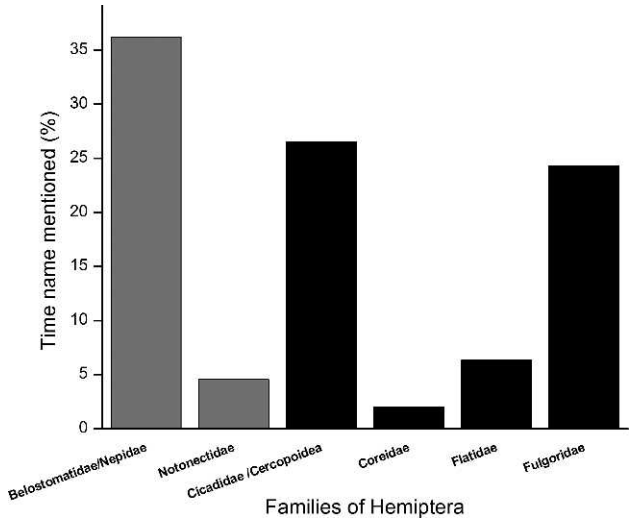

Figure 6. Insects in families of Hemiptera consumed by local people in five sites, Ambatofinandrahana, Anjà, Mahabo, Maroantsetra and Vatomandry in Madagascar. Gray: aquatic; Black: terrestrial.

Coleoptera

Beetles consumed by the informants in the study sites were from both terrestrial and aquatic habitats. Edible adult beetles (71.47%, n=798, number of times Coleoptera was mentioned) were more popular than the larvae (27.76%), which comprised mainly white grubs living underground (Figure 5) or in fallen

Figure 7. *Bora*, *Platypleura andriana* (Cicadidae), consumed in Mahabo Morondava. Photo by Maminirina Randrianandrasana.

branches and logs of wood. Some common names were undefined (0.77%) because it was impossible to identify to stages or families using what little information could be retrieved. Aquatic beetles were primarily diving beetles (Dytiscidae) but some water scavenger beetles (Hydrophilidae) were also consumed (Table 4). Aquatic beetles were less popular (29.31%) than the terrestrial species (73.26%). The latter comprise primarily scarabaeid beetles (subfamily Melolonthinae). The adult stages of beetles are called *voangory* in Malagasy and the larval stages *bongy, lafa*, or *vasatra* depending on the regions (Table 4). Local names usually describe features of the beetles, such as colors (i.e., *mavo,* meaning ''yellow'' and *fotsy vody* meaning ''white rear''), or habitats of the insects including *kakazo*, meaning ''logs of trees,'' *tany,* meaning ''soil,'' and *ravinala,* meaning ''the traveller's tree'' (*Ravenala madagascariensis* Sonn., Strelitziaceae). Some specimens could be identified to species level (Table 4).

Tsikondry and *voangory be* are names given to the pupae of *Proagosternus* sp. and *Tricholespis* sp. (both Scarabaeidae Melolonthinae) according to Decary (1937:170). *Voangory be* could be the name of the species in the adult stage as recorded in our survey, but unfortunately no specimens could be collected to confirm this identification. Some larvae of beetles called *sahobaka* were also recorded but not collected during the survey. Decary (1937:170) defined them as the larvae of *Cladognathus serricornis* Latreille (Lucanidae) or of *Scarites* sp. (Carabidae). *Sahobaka* was also defined as a large cricket by other authors (Grandidier 1907; Lespagnol 1904) but informants described it as more similar to a beetle larva. According to informants who did not consume these insects, *sahobaka* could be found in rice fields but were not really popular (2.5%, n=798, number of times Coleoptera was mentioned). The consumers found them tasty, though, because they are fat like other beetle grubs. The reason for the unpopularity might be the fact that, in the past, people were not allowed to dig out larvae of Coleoptera along the rice fields, in order to protect the irrigated canals. Thus, only privileged or rich people could afford them as they were collected far from the villages (Decary 1937).

Hemiptera

More terrestrial (59.22%, for n=900, number of times Hemiptera were mentioned) than aquatic Hemiptera (40.78%) were consumed by the Malagasy informants (Figure 6). They were consumed in both immature and adult stages. Adults of Cicadidae (Figure 7) and Fulgoridae (Figure 4) were very popular in many regions. The rare informants who did not consume the fulgorid planthopper *sakondry* observed *fady* (taboos) inherited from their ethnic groups. Further studies on the exact reasons for taboos, not known by the informants, should be undertaken to see whether species indigenous to the original localities of the ethnic groups were not considered edible compared to the species in the localities where the informants currently lived or whether other reasons that have historic, hygienic, or social rationales could explain the attitudes (Meyer-Rochow 2009). Other families of terrestrial Hemiptera such as Coreidae were also recorded as edible in Anjà despite the fact that at least one species in this family exudes a defensive smell and was used more like a toy for children than for consumption. Children hold these insects by their antennae, tethering them so that they move faster with their wings in a static position making noise

Table 5. Specimens of edible Hemiptera recorded in Madagascar from January to June 2013 and December 2013.

Scientific name	Family	Common name	Location	Stage consumed
Aquatic true bug				
Hydrocyrius punctatus Stal	Belostomatidae	Giant water bug	Unspecified	Immature/adult
Heleocoris naucoroides Montand.	Naucoridae	Creeping water bug	Unspecified	Immature/adult
Laccotrephes spp.	Nepidae	*Tsingahatra*	Vatomandry	Immature/adult
Unidentified	Belostomatidae/ Nepidae	*Andriamasy*	Anjà	Immature/adult
Unidentified	Belostomatidae/ Nepidae	*Angala, magna*	Anjà	Immature/adult
Unidentified	Belostomatidae/ Nepidae	*Angalabe*	Anjà	Immature/adult
Unidentified	Belostomatidae/ Nepidae	*Lavasiky*	Anjà	Immature/adult
Unidentified	Belostomatidae/ Nepidae	*Tsikahaka*	Maroantsetra	Immature/adult
Unidentified	Belostomatidae/ Nepidae	*Tsindrahaka*	Anjà, Ambatofinandrahana	Immature/adult
Unidentified	Belostomatidae/ Nepidae	*Tsingalapaka*	Anjà	Immature/adult
Unidentified	Belostomatidae/ Nepidae	*Tsingalandrano*	Anjà	Immature/adult
Unidentified	Belostomatidae/ Nepidae	*Tsimahatafitena*	Anjà, Ambatofinandrahana	Immature/adult
Unidentified	Notonectidae	*Tsiditsidika/ kivadikapotsy*	Anjà	Immature/adult
Unidentified	Notonectidae	*Tsipikopiko/ tsipipiko*	Anjà, Mahabo	Immature/adult
Unidentified	Unidentified	*Kitsitititika*	Anjà, Mahabo	Immature/adult
Unidentified	Unidentified	*Pitripitrika*	Anjà	Immature/adult
Unidentified	Unidentified	*Tsingala*	Anjà	Immature/adult
Terrestrial true bug				
Malagasia aperta (Signoret)	Cicadidae Tibicininae	*Angoaka*	Vatomandry	Immature/adult
Malagasia distanti Karsch	Cicadidae Tibicininae	*Gigiky*	Vatomandry	Immature/adult
Platypleura andriana Distant	Cicadidae	*Bora, borahazo, boran-kazo*	Mahabo	Immature/adult
Yanga guttulata (Signoret)	Cicadidae	*Ampandy*	Vatomandry	Immature/adult
Unidentified	Cicadidae/superfamily Cercopoidea	*Ampindy*	Vatomandry	Immature/adult
Unidentified	Cicadidae/superfamily Cercopoidea	*Angoaka*	Vatomandry	Immature/adult
Unidentified	Cicadidae/superfamily Cercopoidea	*Boramena, ikalamena*	Anjà, Mahabo	Immature/adult
Unidentified	Cicadidae/superfamily Cercopoidea	*Boran-tany*	Anjà, Mahabo	Immature/adult

Table 5. Continued.

Scientific name	Family	Common name	Location	Stage consumed
Unidentified	Cicadidae/super family Cercopoidea	*Jorery vaventy*	Anjà	Immature/adult
Unidentified	Cicadidae/super family Cercopoidea	*Pindy, pinjy*	Maroantsetra	Immature/adult
Unidentified	Coreidae	*Agnaogna*	Anjà	Immature/adult
Flatida rosea (Melichar)[a]	Flatidae	*Kiakoholahy*	Anjà, Mahabo, Vatomandry	Secretion (*siramamin'ala*, literally forest sugar)
Flatida coccinea (Auber)[a]	Flatidae	*Kiakoholahy*	Anjà, Mahabo, Vatomandry	Secretion (*siramamin'ala*, literally forest sugar)
Zanna madagascariensis Signoret	Fulgoridae	*Sakondry*	Anjà, Vatomandry	Immature/adult
Zanna tenebrosa (Fabricius)	Fulgoridae	*Sakondry*	Mahabo	Immature/adult
Zanna sp.	Fulgoridae	*Sakondry*	Maroantsetra	Immature/adult

[a] Scientific name associated with the common name according to Decary 1937.

and exuding a defensive secretion. White waxy secretions extruded from the tips of the abdomens of flatid planthoppers congregating on barks of trees were also collected and immediately consumed when encountered because of their sugary taste. The giant water bugs, Belostomatidae, and the water scorpions, Nepidae, were the two families most frequently consumed among all groups of Hemiptera (Figure 6). The data recorded from the two families were combined as it was difficult to differentiate them from the informant's description and common names provided. Backswimmers, Notonectidae, were also collected from water ponds in rice fields and consumed by many fewer people in some sites such as Mahabo. Various common names of Hemiptera were recorded, with some specimens collected and identified to species level (Table 5).

Hymenoptera

Because honey from honey bees and stingless bees is widely consumed and included in Malagasy traditional rituals (Decary 1950), except for rare ethnic groups who cannot eat it for taboo reasons, it merits separate study, so it was not included in the questionnaire. We found out that the larvae and pupae of *Apis mellifera unicolor* (Latreille) (Apidae), the Malagasy honey bee (33.98%, n=103, number of times Hymenoptera was mentioned), and vespid wasps (66.02%), such as *Ropalidia vitripennis* (De Saussure), called *faneni-gasy*, and *Polystes olivaceus* (Degeer), called *faneni-bazaha*, were still considered insect delicacies in Vatomandry only.

Lepidoptera

Lepidoptera consumed by the informants in the study sites were eaten mainly in the pupal stage (72.94%, n=255, number of times Lepidoptera was mentioned), although some informants (27.06%) also consumed the larval stage of a saturniid

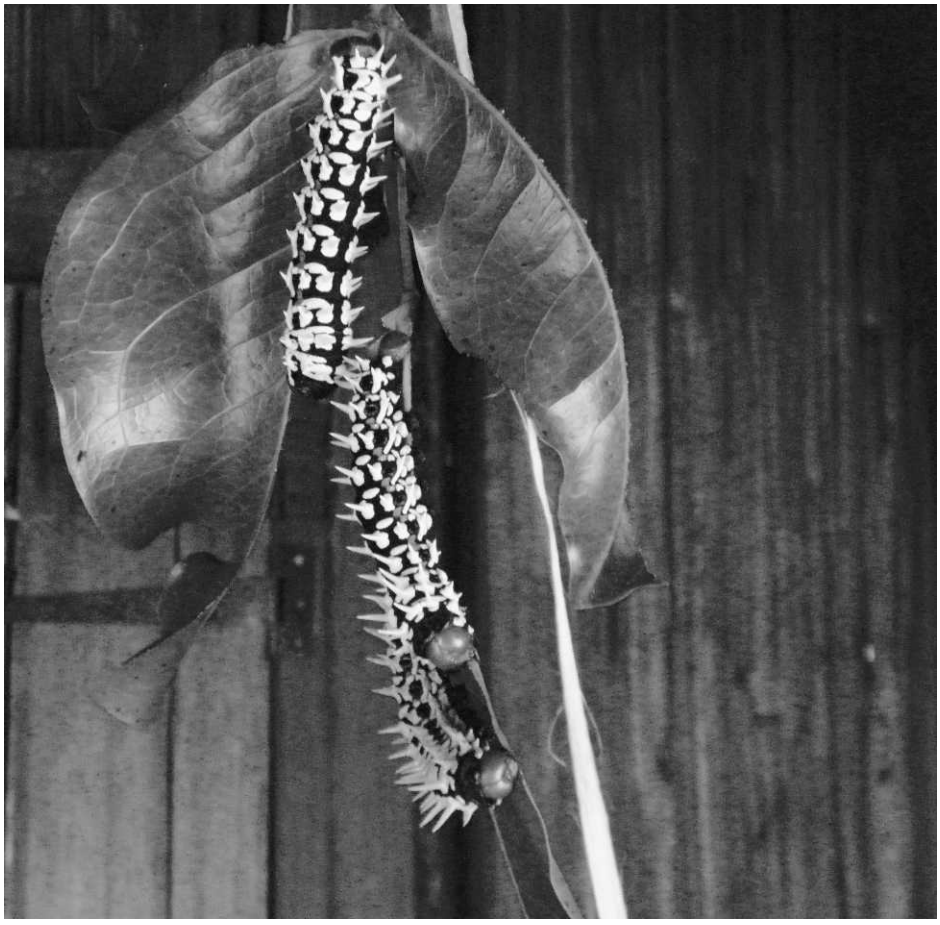

Figure 8. *Sarà*, larvae of *Bunaea aslauga* (Saturniidae), consumed by a small number of people in Madagascar. Photo by Maminirina Randrianandrasana.

species, *Bunaea aslauga* Kirby (Figure 8). Many informants who knew about the edibility of the larvae but did not want to consume them were afraid of the colorful spines covering their body and/or appalled by the preparation mode, as the internal organs must be removed by inverting the body tegument of the larvae with a stick before cooking. Few people used as food the larvae of the domestic silkworm *Bombyx mori* L. (Bombycidae). Most of the pupae consumed (56.86%) belong to the family Lasiocampidae, which is the family of the wild silkworm *B. cajani*, the species predominantly used in Madagascar, including Ambatofinandrahana, for sericulture. Unfortunately, their endemic natural habitats, which are *tapia* forests, have been continuously overexploited and endangered in different regions (Gade 1985; Rakotondrasoa et al. 2012; Razafimanantsoa et al. 2012). Managing sericulture, including collection of the pupae, is restricted to a local community-based association (COBA) and people can still buy them in local markets. This measure sustains sericulture and prevents overexploitation of the silkworms as the pupae must be collected at a particular time during their

Figure 9. Freshly collected large cocoon covering individual cocoons inside of which are found the edible pupae of *Hypsoides* sp. (Notodontidae). Photo by Maminirina Randrianandrasana.

development. The same is true of the Notodontidae (Figure 9) that build a large communal silk nest covering individual cocoons hanging on branches of Lombiro trees (*Rhopalocarpus* spp. and probably *Dialyceras* spp., Sphaerosepalaceae) in the last humid dense forests of Madagascar (Craig 2007). Different species of Notodontidae were collected during their pupal stages for food by a small number of informants in Maroantsetra (6.28%). They were unpopular because they must be prepared and cleaned in a specific way or in a specific time of their pupal stage, usually in earlier stages. Otherwise, the notodontid pupae are bitter and difficult to swallow. There is a possibility that the common names mentioned in Table 6 described more species than we could collect. We suspect that other larvae of saturniids, such as *Tagaropsis* spp., *A. suraka* (Gade 1985), and *Maltagorea fusicolor* (Mabille) (Barsics et al. 2013), could be consumed along with *Borocera* spp. and *Bunaea aslauga* Kirby, as was the case in the *tapia* forests of Arivonimamo in midwestern Madagascar (Barsics et al. 2013), which are similar to the type of forests in Ambatofinandrahana.

Orthoptera

Locusts have long been a part of the cuisine appreciated by many Malagasy people. Travellers from the seventeenth century mentioned locust consumption (Grandidier and Grandidier 1903–1920). Political crises hampering the regular prevention of locust migration led in 2012–2013 to an intense invasion by the Malagasy migratory locust, *Locusta migratoria capito*, from the south to the central

Table 6. Specimens of edible Lepidoptera recorded in Madagascar from March to June 2013.

Scientific name	Family	Common name	Location	Stage consumed
Bombyx mori Linnaeus	Bombycidae	*Landikely, zana-dandy*	Anjà, Ambatofinandrahana	Pupa
Borocera cajani Vinson	Lasiocampidae	*Landibe, bibin-dandy, zana-dandy*	Anjà, Ambatofinandrahana	Pupa
Hypsoides antsianakana Oberthür[a]	Notodontidae	*Saràna, mondra lombiry*	Maroantsetra	Pupa
Hypsoides diego Coquerel[a]	Notodontidae	*Saràna, mondra lombiry*	Morondava	Pupa
Hypsoides radama Coquerel[a]	Notodontidae	*Saràna, mondra lombiry*	Maroantsetra	Pupa
Hypsoides semifusca Kiriakoff[b]	Notodontidae	*Saràna, mondra lombiry*	Maroantsetra	Pupa
Hypsoides singularis Kiriakoff[a]	Notodontidae	*Saràna, mondra lombiry*	Maroantsetra	Pupa
Antherina suraka (Boisduval)	Saturniidae	*Saràna, soherina, sarohy*[c]	Maroantsetra	Pupa, larva[c]
Bunaea aslauga Kirby	Saturniidae	*Kijaja, sarà, sarohy*	Anjà, Ambatofinandrahana, Arivonimamo	Larva
Unidentified	Saturniidae	*Kitsahitsahy, kizazy*	Ambatofinandrahana	Larva
Unidentified	Mostly Lasiocampidae but a few Bombycidae/ Saturniidae	*Mondra, mondry*	Maroantsetra, Mahabo	Pupa
Unidentified	Mostly Lasiocampidae but a few Bombycidae/ Sphingidae/ Saturniidae	*Bambara, goreka*	Anjà, Ambatofinandrahana	Other stage than larva (pupa and few adults)

[a] Presence recorded from PBZT insect collection.
[b] Presence recorded from Craig 2007.
[c] Larval stage not mentioned by informants but recorded from Gade (1985).

regions of Madagascar, and some parts of the north of Madagascar (Figure 10). Mixed populations of the migratory locusts and the red locust, *Nomadacris septemfasciata*, were even observed in some areas, such as Mandritsara (Office for the Coordination of Humanitarian Affairs 2013), where people from Maroantsetra sometimes visited families; there, they sampled the locusts offered as a meal. The lack of preventative treatment in many areas drove many local people to using traditional practices, collecting locusts in baskets, boiling, and sun-drying them on mats for future consumption (Figure 11). Fresh or dried locusts were greatly appreciated during invasions, as they can be served for a number of months accompanying the rice staple as side dishes fried or cooked with fat or meats such as pork.

Almost all families of Orthoptera found in the field were consumed. They could comprise an entire meal when gathered in great numbers, as was the case with locusts, or, when they are found in smaller numbers, they are collected by

Figure 10. A swarm of locusts invading rice fields in May 2013 in Fianarantsoa and people trying to collect them in bags and buckets. Photo by Hermond Randrianandrasana.

children and grilled directly on a fire. A variety of names are used to describe edible grasshoppers, locusts, and katydids (Table 7) with some specimens identified to species level. Only the rainbow milkweed locust, *Phymateus saxosus* Coquerel (Pyrgomorphidae), was not consumed because it secretes unpleasant odors attributable to its milkweed diet. It is called *valalan'alika* or *valalan'amboa* in Malagasy, meaning literally ''grasshopper of dogs,'' or *valalandolo* meaning ''dead person soul's grasshopper.'' Species in another group of Orthoptera, the crickets, were also consumed, although they were not popular (3.37%, n=247, number of times Orthoptera was mentioned).

Odonata

Odonata were consumed in immature stages by relatively few informants (3.14%, n=2512, number of times Odonata was mentioned). The most widely utilized species are large dragonflies (Anisoptera) in the family Aeschnidae or Libellulidae (Table 8); fewer Zygoptera (damselflies) might be accidentally collected as usually they were caught with other aquatic insects during net or basket fishing in the rice fields. They were referred to by the informants in different ways describing their specific features: *angidindrano,* meaning ''water dragonflies,'' *antibavimatôtra*, meaning ''an old woman sitting,'' which describes the carnivorous immature dragonfly waiting for its prey.

Consumption Mode

Most of the informants consumed insects and orb-weavers grilled when they collected a small number; more precisely, they placed them directly on fires or roasted them on sticks over a fire. Before cooking, some larger arthropods such as orb-weavers needed to be cleaned by removing their internal organs and/or their legs. Legs of these edible arthropods were sometimes not removed as they were so thin and brittle when roasted that they easily broke by themselves. Heads of

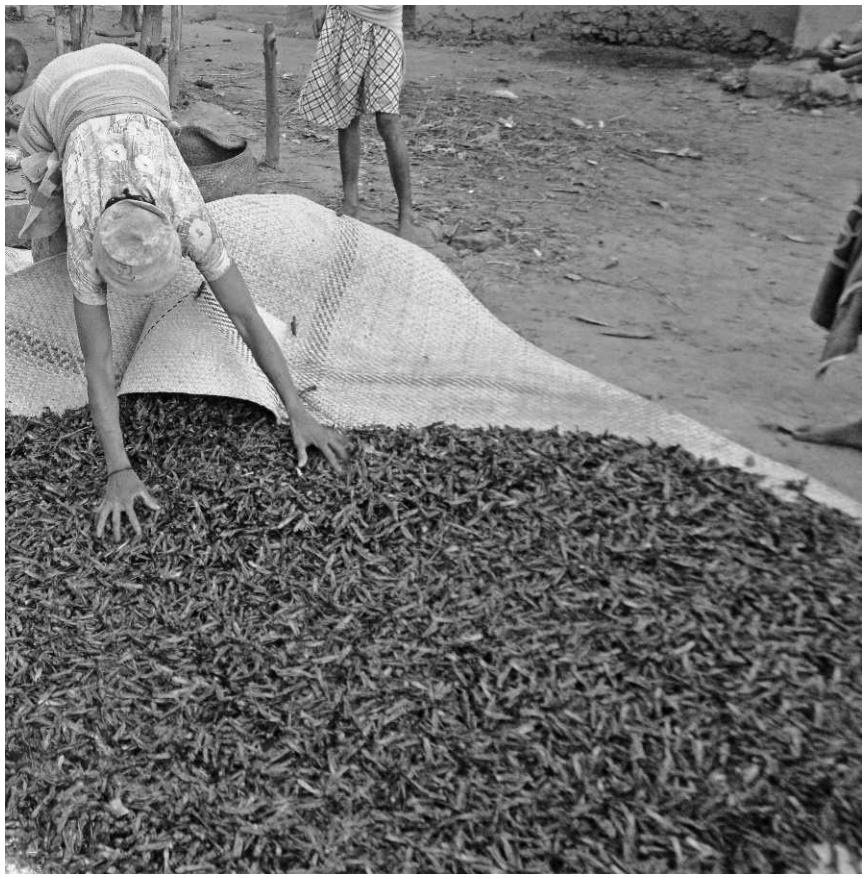

Figure 11. A woman filling a basket with locusts sun-dried on a mat, for storage indoors during the night. Photo by Maminirina Randrianandrasana.

diving beetles were removed right after collection, possibly because of fear of being bitten. When insects were collected in larger numbers, such as locusts, they were boiled and sun-dried. Then wings and appendages were removed and the remaining body parts were soaked in salted water and then pan-fried in animal fat or vegetable oil. Insects with a great amount of fat such as rhinoceros beetle larvae do not need oil; a small amount of water is used that will dry quickly and let the fat melt. According to the informants, some insects, such as *tsindrahaka* (either Nepidae or Belostomatidae), are distasteful if directly grilled. Insects can also be stewed by adding available seasoning ingredients such as onions, garlic, tomatoes, black peppers, and curry spices, a currently typical cuisine style for cooking meat in Madagascar. Insects such as locusts and silkworm pupae are also accompanied by other meat such as pork to provide more varied flavors to the dish. However, one informant did not recommend onions when cooking larval or pupal stages of Saturniidae because this individual believed that the mixture could be harmful, although without specifying why that is the case. No edible arthropods in pickled condition were recorded in our study.

Table 7. Specimens of edible Orthoptera recorded in Madagascar from March to June 2013 and December 2013. *Kijeja* designates the immature stage of most acridids.

Scientific name	Common name	Family	Location
Locusta migratoria capito Saussure	*Valalamena* (Migratory locust)	Acrididae	Anjà, Ambatofinandrahana, Mahabo
Nomadacris septemfasciata Audinet-Serville	*Valalamena* (Red locust)	Acrididae	Anjà, Ambatofinandrahana, Mahabo
Cyrtacanthacris sp.[a]	Grasshopper	Acrididae	Unspecified
Brachytrupes membranaceus[a] (Drury)	*Sahobaka*[b]	Acrididae	Unspecified
Odontolakis sexpunctata (Serville)[b]	*Ampangan'akondro*	Tettigoniidae	Vatomandry
Unidentified	*Angely, Kiangily*	Gryllidae	Anjà
Unidentified	*Kiangily mainty*	Gryllidae	Anjà
Unidentified	*Mendry*	Unidentified	Maroantsetra
Unidentified	*Kifilifily*	Unidentified	Anjà
Unidentified	*Kindava*	Unidentified	Anjà
Unidentified	*Kindra*	Unidentified	Anjà
Unidentified	*Kipapasy*	Unidentified	Anjà
Unidentified	*Valala gambo*	Unidentified	Anjà
Unidentified	*Valala maitso*	Unidentified	Anjà
Unidentified	*Valala zana-tany*	Unidentified	Anjà

[a] Not collected but presence recorded from Defoliart (2002).
[b] Name associated with a cricket instead of a beetle (Grandidier 1907; Lespagnol 1904).

Availability of Edible Insects

According to the informants, apart from aquatic insects and grasshoppers that were available throughout the year, few species could be consumed during the rainy season, in contrast with the dry season, when the fulgorid planthoppers, *sakondry*, were mostly consumed (Table 9). Periods of availability of edible insects were then associated with the period when the farmers experienced the greatest difficulties in food provision (Table 10). High consumption of edible insects by the informants was recorded during the period

Table 8. Specimens of edible larval stage of Odonata collected in Madagascar from March to June 2013.

Scientific name	Common name	Family	Location
Anax spp. and other genera	*Tsikina*	Mostly Aeschnidae	Ambatofinandrahana
Trithemis spp. and other genera	*Ondrindrano*	Libellulidae	Mahabo
Anax spp., *Trithemis* spp. and other genera	*Valohotraka*	Aeschnidae or Libellulidae	Anjà
Anax spp. and other genera	*Antibavimatòtra*	In the group of Anisoptera	Maroantsetra
Unidentified	*Bedobòka*	In the group of Anisoptera	Mahabo
Unidentified	*Betabòka*	In the group of Anisoptera	Anjà
Unidentified	*Fangorinan-drano, fanorinan-drano, renin'angidina, vatan'oron-dRasamy*	In the group of Anisoptera	Anjà, Ambatofinandrahana

Table 9. Availability of edible insects and orb-weavers throughout the year in Madagascar according to the informants participating in the survey.

Season	Edible insects available
All seasons	aquatic insects (diving beetles, dragonfly nymphs, Belostomatid and water scorpions, backswimmers)
	grasshoppers
	pupae of silkworms (collected or reared, but localized availability)
October to March (Mainly hot and rainy season)	adult and larvae of terrestrial beetles
	wax secretion of flatid planthoppers
	adult Cicadidae
	larvae of Saturniidae
	adult of moths such as hawk moths (Sphingidae)
	pupae of notodontid moths
April to September (Mainly cool and dry season)	fulgorid planthoppers
Periodically	locusts (during pesticide-free infestations)

from October through December. These months comprise the first half of the lean season, which is from October to March (Minten and Barrett 2008), and is mainly a period between exhaustion of rice reserves and rice harvest in March. Delay or drought and increased food prices worsened the situation from January to March (Badjeck et al. 2013). January and February seemed to be the worst months for food security as all of the factors affecting food security are operative (Table 10). Using insects that remain available as food during these months would help in supplementing protein intake.

These edible insects were usually collected by farmers in the crop fields or in the forests but could also be purchased in local markets or from the collectors during peaks in abundance. From March to June 2013, the months we conducted the survey, locusts were sold in the open markets in the areas of infestation such as Anjà, Ambatofinandrahana, and Mahabo, but silkworm pupae and aquatic insects only in Ambatofinandrahana (Figure 12), and wasp larvae and pupae only in Vatomandry. Collecting techniques were simple: hand-picking or using baskets as sieves for aquatic insects and then using emptied bottles or baskets to

Table 10. Availability of edible insects according to the informants compared to factors affecting food security.

Months of the year												Factors affecting food security
S	O	N	D	J	F	M	A	M	J	J	A	
	■	■	■	▒	▒	▒						Higher availability of edible insects
				▒	■	▒						Lack or delay of precipitation
	▒	▒	▒	▒	▒	▒						Lean season
				▒	▒							Lowest availability of cereal crops (especially rice)
▒	■	▒		▒	■	▒						Hike in food prices

Source: Minten and Barrett (2008) and Badjeck et al. (2013).
Note: Black = peak, gray = present.

Figure 12. Aquatic insects (upper left), silkworm pupae (upper right), and locusts (bottom) sold in local market places in Ambatofinandrahana and Mahabo. Photo by Maminirina Randrianandrasana.

carry them. Most of the farmers, both men and women, know how to collect insects by the time they are adults as this is part of children's playtime activities.

General Conclusions

Despite the difficulty classifying edible insects to species, the results of the survey showed that Madagascar is rich in edible insects, as reflected by the diversity of common names used to describe species eaten at different sites. Species richness was particularly high for edible Coleoptera and Orthoptera. More than ten common names were used by the local people to differentiate to morpho-species members of these two orders in Anjà. Further study relating to identification to scientific names of these common names would complete the list of edible insects. However, this study was limited to five sites with 17 subsites. Thus, these results might not reflect trends in consumption of edible non-crustacean arthropods across the entire country. Notwithstanding, it can definitively be stated that the informants' tastes at the five sites reflected trends in entomophagy worldwide, especially in the Indo-Malayan and Afrotropical zones, except for some peculiarities such as the absence of termite eating.

Problems of nutrition persist in rural areas even if edible arthropods are diverse and available during difficult times and lean seasons for farmers. This might be because of acculturation of western values from overseas missionaries

and administrators (Gade 1985). Consuming insects also appears to be more of an opportunistic behavior, as people consumed them only when they encountered them—during the height of their availability. In fact, food consumption patterns are strongly related to local availability, such as local food supply and local cultures (Cardoso et al. 2013; Nestle et al. 1998). This pattern was confirmed in our study with respect to people in Ambatofinandrahana, who live closer to sericulture centers and eat silkworm pupae. The abundant species, such as fulgorid planthoppers and locusts, were either seasonal or periodical, and were appreciated as family meals by the people in the regions where they were found. Some of the edible arthropods collected, such as diving beetles and orb-weavers, were not abundant enough for a family meal so that they were mainly collected by children for snacking.

Rearing edible insects could be a workable strategy to improve availability. Commercially reared saturniid pupae of *A. suraka* for a novel wild sericulture enterprise are already being considered in trials in Maroantsetra by the nongovernmental organization Conservation through Poverty Alleviation International (CPALI). Sericulture, entomophagy, and apiculture have been all used traditionally in different parts of Madagascar (Decary 1950) and in other countries (Raina et al. 2009; Schabel 2006). These insect-based activities could be improved to tackle pressing economic issues, including food security and community-based conservation in riparian forests in the region, by providing extra cash to local people who need alternative income to overcome difficult times during the lean season. However, it must be emphasized that learning the biology of any species being considered for farming as a source of alternative income for community-based conservation is an essential prerequisite for designing a sustainable enterprise. As an example, the biology of *Hypsoides* spp. in Maroantsetra should be learned in order to rear the edible species. Not all consumers of the pupae of these species possessed proper knowledge of their life cycle, collecting them at a time in the cycle when they were bitter and consequently throwing them away.

Ethnoentomological knowledge from local people has great value in insuring sustainability and conservation of edible insects (Ramos-Elorduy 2009). Educating the local people in general entomology was essential to facilitate documentation of the identity of edible species because common names often do not correspond to the appropriate classes or orders. Thus, partnerships between local populations and the professional entomological community will likely provide the best foundation on which to build sustainable production systems for edible arthropods in Madagascar.

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