THE NEW NATURAL HISTORY OF

MADAGASCAR

EDITED BY STEVEN M. GOODMAN

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EDIBLE TERRESTRIAL ARTHROPOD TRADITIONS AND USES ON MADAGASCAR

B. L. Fisher and S. Hugel

In 1861, Emperor Napoleon III of France sent Dr. Auguste Vinson to Madagascar to attend the coronation of King Radama II. When the French envoy met the new ruler, the king's 10-year-old son was also present. Young Jon's pockets, Vinson reported, were filled with roasted pupae of the wild silkworm (*Borocera cajani*, Lasiocampidae), which he snacked on during the interview (1863c: 47; 1865: 310). Vinson was not the first visitor to observe the Malagasy custom of eating insects. Still, his story highlights two important aspects of edible-insect traditions on Madagascar. First, the culture of eating insects has long been widespread on the island—a tasty treat for hungry farmers and the highest members of the Merina Dynasty alike. Second, the most enthusiastic insect consumers on Madagascar, even today, are children.

Here we review the history of consumption of insects (entomophagy) and spiders on the island, and provide a list of commonly consumed species. We discuss past culinary practices, and suggest that edible insects offer a sorely needed solution to current social, nutritional, and biodiversity concerns on the island. The prevalence of insect consumption, species preferences, and preparations of the past provide a historical context for improving current efforts to use insects to address food insecurity and biodiversity preservation concerns on Madagascar.

EARLY ACCOUNTS

Early records of edible insects on Madagascar include discussion of three principal groups: fulgorids (Flatidae; see Świerczewski and Stroiński, pp. 987–91), moths (order Lepidoptera; see Lees and Minet, pp. 1141–72), and locusts (order Orthoptera; see Hugel, pp. 996–1014). Early records also include arachnids (order Araneae; see Wood and Griswold, pp. 878–93). These groups captured the interest of early travelers for different reasons. The fulgorids produced candy-like "manna"; the dual-purpose moths and spiders were both eaten and produced silk; and the dramatic swarms of locusts destroyed crops but were a cherished food staple across Madagascar. Our review focuses just on the literature that relates to insects and spiders as food or their potential as a food source. Honey and beeswax are another prevalent topic mentioned in very early reports (e.g., Cauche 1651: 35, 53, 78; Carpeau du Saussay 1722: 244), but here we limit the discussion of Hymenoptera to the consumption of larvae.

The principal publications documenting the practice and uses of edible insects on Madagascar include Flacourt (1658 [repr. 1995]; Hemiptera, Lepidoptera), Vinson (1863a, 1863b, 1863c; Araneae, Lepidoptera), Coquerel (1856, 1866; Lepidoptera), Sibree (1884; Orthoptera), Camboué (1886, 1888; Orthoptera), Grandidier and Grandidier (1908; insects in general), Perrier de la Bâthie (1905; insects eaten by the Sakalava), Decary (1925; Orthoptera), Zolotarevsky (1930; Orthoptera), Decary (1931, 1937, 1951; insects in general), and Gade (1985; tapia woodland insects) (see Kull and Birkinshaw, pp. 121–27). Other works that provide context for edible insects include Pollen (1868), Leguével de Lacombe and de Froberville (1840), W. Ellis (1858), Pfeiffer (1861), Lacaze (1881), and Osborn (1924). In most cases we are able to link discussions in the literature to current scientific names (Table 5.4).

The following works should not be viewed as primary sources. They summarize information from previous publications that include erroneous records from Madagascar: Hope (1842), Simmonds (1859, 1885), Sachot (1864), Macquarie (1884), Holt (1885), Bergier (1941), Théodoridès (1949), Bodenheimer (1951), Ramos-Elorduy et al. (2009), van Huis et al. (2013), Malaisse and Latham (2014), Dossey et al. (2016), and Mitsuhashi (2016). Since 2010, a growing number of studies have described modern insect-eating practices on Madagascar (Barsics et al. 2013a, 2013b; Randrianandrasana and Berenbaum 2015; Van Itterbeeck et al. 2019; Dürr et al. 2020); when appropriate, these are included in Table 5.4 and discussed below.

COLEOPTERA

Beetles are considered good sources of food in communities across the island. During their trip to Madagascar from May to September 1857, Joseph Lambert and Ida Pfeiffer were regularly invited to dine by Queen Ranavalona I. At these banquets, "the most exquisite treats (naturally for the palates of the natives) were served, among others ground and water beetles which, especially the last ones pass for delicious" (Pfeiffer 1861, our translation). Vinson (1863c: 45–46) found a number of beetle species being consumed and described how they were prepared. Along the irrigation channels of rice fields, scarab (Scarabaeidae) beetle larvae were dug up from the soil at about 20 cm depth. When boiled or fried, he noted, the larvae are considered quite tasty. Grandidier (1869: 154) observed that because excess digging for the larvae could damage irrigation channels for rice fields, these insects were collected far from villages, limiting their availability. In 1868–1869, Lacaze (1881: 67) noticed baskets containing beetle larvae in an Antananarivo market.

Large terrestrial beetles are consumed most often on Madagascar. These include species from the families Carabidae, Cerambycidae, Curculionidae, Lucanidae, Passalidae, and Scarabaeidae. Readily available near villages, they are eaten as larvae, pupae, and adults. The larvae are prized and often fried in their own fat or roasted with a little salt on hot coals. Charpentier de Cossigny (1799: 329), based on observations in 1773, noted the Malagasy ate palm weevil larvae raw. Today, adult beetles are often collected and eaten by children (Figures 5.9c–e). On B. Fisher's first visit to Madagascar in 1992, he saw children filling a *kapaoka* (a tin can) with adult Melolonthinae (Scarabaeidae) found on vegetation around a village at the edge of the Andohahela protected area.

TABLE 5.4. **Edible insects and arachnids consumed on Madagascar, which based on the literature includes records of one edible spider species and at least 101 edible insect species**

CLASSIFICATION	SPECIES	REFERENCES (OFTEN INCLUDING FIRST REFERENCE)
Araneae: Araneidae	*Nephila inaurata madagascariensis* (Vinson, 1863)	Vinson (1863d)
Coleoptera: Carabidae	*Scarites* sp.	Decary (1937); Barsics et al. (2013a); Randrianandrasana and Berenbaum (2015); Dürr et al. (2020)
Coleoptera: Cerambycidae	*Batocera rufomaculata* (De Geer, 1775)	Randrianandrasana and Berenbaum (2015)
Coleoptera: Curculionidae	*Eugnoristus monachus* Schoenherr, 1838	Bodenheimer (1951, stated without referencing); Barsics et al. (2013a)
	Rhina sp.	Bodenheimer (1951, stated without referencing); Barsics et al. (2013a)
	Rhynchophorus phoenicis Schoenherr, 1825	Probably what Vinson (1863c) refers to as "Conocephalas Guerini (Calandride)," B. Fisher (unpublished data)
	Rhynchophorus sp.	Bodenheimer (1951, stated without referencing); Barsics et al. (2013a); Dürr et al. (2020)
Coleoptera: Dytiscidae	*Cybister* spp.	Six species cited but with questionable identification: Decary (1937); Barsics et al. (2013a); Randrianandrasana and Berenbaum (2015)
	Rhantus latus (Fairmaire, 1869)	Ramos-Elorduy et al. (2009, stated without referencing)
Coleoptera: Gyrinidae	*Dineutus sinuosipennis* Laporte, 1840	Possibly the *Dineutus* sp. recorded by Randrianandrasana and Berenbaum (2015)
Coleoptera: Hydrophilidae	*Sternolophus* sp.	Randrianandrasana and Berenbaum (2015)
Coleoptera: Lucanidae	*Prosopocoilus serricornis* (Latreille, 1817)	Decary (1937); Barsics et al. (2013a); Randrianandrasana and Berenbaum (2015)
Coleoptera: Passalidae	Palmicolous passalid	Théodoridès (1949, citing a correspondence from R. Paulian); Barsics et al. (2013a)
Coleoptera: Scarabaeidae, Cetoniinae	*Bricoptis variolosa* (Gory & Percheron, 1833)	Dürr et al. (2020)
Coleoptera: Scarabaeidae, Dynastinae	*Hexodon unicolor* Olivier, 1789	Dürr et al. (2020)
	Oryctes boas (Fabricius, 1775)	Randrianandrasana and Berenbaum (2015)
	O. gigas Castelnau, 1840	Randrianandrasana and Berenbaum (2015)
	O. pyrrhus Burmeister, 1847	Randrianandrasana and Berenbaum (2015)
Coleoptera: Scarabaeidae, Melolonthinae	*Amphimallon solstitiale* (Linnaeus, 1758)	Dürr et al. (2020)
	Enaria limbalis Fairmaire, 1900	Randrianandrasana and Berenbaum (2015)
	Hoplochelus marginalis (Fairmaire, 1889)	Randrianandrasana and Berenbaum (2015)
	Hoplochelus spp.	Randrianandrasana and Berenbaum (2015)
	Phyllophaga sp.	Dürr et al. (2020)
	Proagosternus sp.	Decary (1937); Randrianandrasana and Berenbaum (2015)
	Proagosternus sp.	Barsics et al. (2013a)
	Serica sp.	Dürr et al. (2020)
	Tricholepis sp.	Decary (1937); Randrianandrasana and Berenbaum (2015); could be the Hannetons of Vinson (1863a)

(*continued overleaf*)

TABLE 5.4. ***continued***

CLASSIFICATION	SPECIES	REFERENCES (OFTEN INCLUDING FIRST REFERENCE)
Hemiptera: Belostomatidae	*Hydrocyrius punctatus* (Stål, 1865)	Probably the "aquatic cockroaches" of Lacaze (1881); Randrianandrasana and Berenbaum (2015)
Hemiptera: Cercopoidea	Indet.	Randrianandrasana and Berenbaum (2015); Dürr et al. (2020)
Hemiptera: Cicadidae	*Malagasia aperta* (Signoret, 1860)	Randrianandrasana and Berenbaum (2015)
	M. distanti (Karsch, 1890)	Randrianandrasana and Berenbaum (2015)
	Yanga andriana (Distant, 1899)	Randrianandrasana and Berenbaum (2015)
	Y. guttulata (Signoret, 1860)	Randrianandrasana and Berenbaum (2015)
Hemiptera: Flatidae	*Flatida coccinea* (Auber, 1955)	Randrianandrasana and Berenbaum (2015)
	F. rosea (Melichar, 1901)	Decary (1937); Randrianandrasana and Berenbaum (2015)
Hemiptera: Fulgoridae	*Zanna tenebrosa madagascariensis* (Signoret, 1860)	Gade (1985); Randrianandrasana and Berenbaum (2015)
	Z. tenebrosa (Fabricius, 1775)	Decary (1937); Randrianandrasana and Berenbaum (2015)
Hemiptera: Naucoridae	*Heleocoris naucoroides* Montandon, 1897	Randrianandrasana and Berenbaum (2015)
Hemiptera: Nepidae	*Laccotrephes* sp.	Probably the "nepa" of Decary (1937) and of Randrianandrasana and Berenbaum (2015)
Hemiptera: Notonectidae	Indet.	Randrianandrasana and Berenbaum (2015)
Hymenoptera: Apidae	*Apis mellifera unicolor* (Latreille, 1804)	Grandidier (1908); Perrier de la Bâthie (1905); Bodenheimer (1951), Randrianandrasana and Berenbaum (2015)
	Liotrigona madecassa (Saussure, 1890)	Grandidier (1908)
Hymenoptera: Vespidae	*Polistes olivaceus* (De Geer, 1773)	Mostly likely the *Polistes* referred to by Perrier de la Bâthie (1905) and Grandidier and Grandidier (1908); Decary (1937); Randrianandrasana and Berenbaum (2015)
	Ropalidia vitripennis (Saussure, 1899)	Randrianandrasana and Berenbaum (2015)
Lepidoptera: Bombycidae	*Bombyx mori* (Linnaeus, 1758)	Buet (1883: 28): "The Hovas naturalized in Antananarivo / mulberry and silkworm from China"; Conte (1910); after Fauchère (1914), introduced by Jean Laborde around 1844
Lepidoptera: Lasiocampidae	*Borocera cajani* Vinson, 1863	Vinson (1863d); Trimoulet (1865); Coquerel (1866); Decary (1937); Barsics et al. (2013); Randrianandrasana and Berenbaum (2015)
	B. madagascariensis Boisduval, 1833	Decary (1937); Gade (1985)
	B. marginepunctata Guérin-Méneville, 1844	T. Razafimanantsoa (unpublished data)
	Europtera punctillata Saalmüller, 1844	Randrianandrasana and Berenbaum (2015, as indet.); T. Razafimanantsoa (unpublished data)
Lepidoptera: Limacodidae	*Latoia albifrons* Guérin-Méneville, 1844	Vinson (1863a); Decary (1937); Barsics et al. (2013)
	L. singularis (Butler, 1878)	Barsics et al. (2013)
	Parasa ebenaui (Saalmüller, 1878)	Barsics et al. (2013)
Lepidoptera: Notodontidae	*Hypsoides antsianakana* (Oberthür, 1922)	Randrianandrasana and Berenbaum (2015)
	H. diego (Coquerel, 1855)	Decary (1937); Randrianandrasana and Berenbaum (2015)
	H. radama (Coquerel, 1855)	Decary (1937); Randrianandrasana and Berenbaum (2015)

CLASSIFICATION	SPECIES	REFERENCES (OFTEN INCLUDING FIRST REFERENCE)
	H. semifusca Kiriakoff, 1969	Randrianandrasana and Berenbaum (2015)
	H. singularis Kiriakoff, 1969	Randrianandrasana and Berenbaum (2015)
Lepidoptera: Psychidae	*Deborrea malgassa* (Heylaerts, 1884)	Decary (1931: 290); Decary (1937); Portier (1949, as *Psyche joannisii*); Bourgogne (1984); Grubenmann and Madle (2016)
Lepidoptera: Saturniidae	*Antherina suraka* (Boisduval, 1833) subsp. *suraka*	Decary (1937); Randrianandrasana and Berenbaum (2015); M. Ratsimbazafy (Sepali, unpublished data)
	Argema mittrei (Guérin-Méneville, 1847)	M. Ratsimbazafy (Sepali, unpublished data)
	Bunaea aslauga Kirby, 1877	Trimoulet (1865); Gade (1985); Barsics et al. (2013); Randrianandrasana and Berenbaum (2015)
	Ceranchia apollina Butler, 1878	M. Ratsimbazafy (Sepali, unpublished data)
	Maltagorea fusicolor (Mabille, 1879)	Gade (1985); Barsics et al. (2013)
	Hippotion gracilis (Butler, 1875)	Randrianandrasana and Berenbaum (2015) as indet. but this is the likely species
Lepidoptera: Sphingidae	Indet.	Decary (1931); DeFoliart (2002)
Odonata: Aeshnidae	Indet.	Randrianandrasana and Berenbaum (2015)
Odonata: Libellulidae	Indet.	Decary (1937); Randrianandrasana and Berenbaum (2015)
Orthoptera: Caelifera	*Acorypha decisa* (Walker, 1870)	Van Itterbeeck et al. (2019)
	Acrida madecassa (Brancsik, 1893)	Van Itterbeeck et al. (2019)
	Acrida sp.	Van Itterbeeck et al. (2019)
	A. subtilis Burr, 1902	Van Itterbeeck et al. (2019)
	Aiolopus thalassinus rodericensis (Butler, 1876)	May correspond to "*Epacromia*" cited in Camboué (1888: 796); Van Itterbeeck et al. (2019)
	Atractomorpha acutipennis (Guérin-Méneville, 1844)	Van Itterbeeck et al. (2019)
	Calephorus ornatus (Walker, 1870)	Van Itterbeeck et al. (2019)
	Catantopsis malagassus Karny, 1907	In Camboué (1888: 796) misidentified as *Catantops debilitatus*, but the Malagasy name given in the text corresponds to *C. malagassus* in Braud et al. (2014); Van Itterbeeck et al. (2019)
	C. sacalava (Brancsik, 1893)	Van Itterbeeck et al. (2019)
	Cyrtacanthacris tatarica (Linnaeus, 1758)	In Camboué (1888: 796) misidentified as *Anacridium aeruginosum*, but the Malagasy name given in the text corresponds to *C. tatarica* in Braud et al. (2014); Van Itterbeeck et al. (2019)
	Duronia chloronota (Stål, 1876)	Van Itterbeeck et al. (2019)
	Eyprepocnemis smaragdipes Bruner, 1910	Van Itterbeeck et al. (2019)
	Finotina radama (Brancsik, 1893)	Van Itterbeeck et al. (2019)
	Gastrimargus africanus madagascariensis Sjöstedt, 1928	Van Itterbeeck et al. (2019)
	Gelastorhinus edax Saussure, 1899	Van Itterbeeck et al. (2019)
	Gymnobothrus madacassus Bruner, 1910	Van Itterbeeck et al. (2019)

(*continued overleaf*)

TABLE 5.4. ***continued***

CLASSIFICATION	SPECIES	REFERENCES (OFTEN INCLUDING FIRST REFERENCE)
	G. variabilis Bruner, 1910	Van Itterbeeck et al. (2019)
	Heteracris nigricornis (Saussure, 1899)	Van Itterbeeck et al. (2019)
	Lemuracris longicornis Dirsh, 1966	Van Itterbeeck et al. (2019)
	Locusta migratoria migratorioides (Reiche & Fairmaire, 1849)	Sibree (1884: 412), as *Ædipoda migratoria* in his dictionary); Richardson (1885) indicated that *valala* correspond to *Æ. migratoria*; Camboué (1886: 172n, as *Locusta* sp.); Camboué (1888: 796, as *Pachytilus migratorioides*); Perrier de la Bâthie (1924, as *P. migratorioides*); Decary (1925, as *P. migratorioides*); Randrianandrasana (2014); Dürr et al. (2020); Van Itterbeeck et al. (2019)
	Nomadacris septemfasciata (Serville, 1838)	Gade (1985); Randrianandrasana (2014); Van Itterbeeck et al. (2019)
	Oedaleus virgula (Snellen van Vollenhoven, 1869)	In Camboué (1888: 796) as *Oedaeus* sp., and only *O. virgula* occurs on Madagascar (see Hugel, pp. 996–1014); Van Itterbeeck et al. (2019)
	Oxya hyla Serville, 1831	Camboué (1888: 796) as *Oxya* sp., and only *O. hyla* occurs on Madagascar (see Hugel, pp. 996–1014); Van Itterbeeck et al. (2019)
	Paracinema tricolor (Thunberg, 1815)	Camboué (1888: 796); Van Itterbeeck et al. (2019)
	Rhadinacris schistocercoides (Brancsik, 1893)	Van Itterbeeck et al. (2019)
	Rubellia nigrosignata Stål, 1875	Camboué (1888: 796); Van Itterbeeck et al. (2019)
	Trilophidia cinnabarina Brancsik, 1893	Van Itterbeeck et al. (2019)
Orthoptera: Ensifera	*Brachytrupes membranaceus colosseus* Saussure, 1899	Gade (1985: 121); Van Itterbeeck et al. (2019)
	Brachytrupes sp.	Grandidier and Grandidier (1908: 208, as *sahobaka*); Van Itterbeeck et al. (2019)
	Colossopus sp.	Van Itterbeeck et al. (2019)
	Conocephalus cf. *affinis*	*Conocephalus* sp. in Camboué (1888: 796); Van Itterbeeck et al. (2019)
	Fryerius sp.	Van Itterbeeck et al. (2019)
	Gryllus sp.	Van Itterbeeck et al. (2019); may correspond to the species identified as *Gryllus bimaculatus* in Dürr et al. (2020)
	Odontolakis sexpunctata (Serville, 1838)	Randrianandrasana (2014: 151)
	Modicogryllus sp.	Van Itterbeeck et al. (2019)
	Phaneroptera sparsa Stål, 1857	Van Itterbeeck et al. (2019)
	Phaneropterinae sp.	Van Itterbeeck et al. (2019)
	Pteronemobius malgachus (Saussure, 1877)	Van Itterbeeck et al. (2019)
	Ruspolia differens (Serville, 1838)	Van Itterbeeck et al. (2019)
	Ruspolia sp.	Van Itterbeeck et al. (2019)

Notes: "Indet." indicates unidentified species. The mention of consumption of the house cricket *Acheta domesticus* in Dürr et al. (2020) is most likely wrong, since this species does not occur on Madagascar (see Hugel, pp. 996–1014). The name "*Locusta cernensis*," sometimes cited in the literature on edible insects, was invented by Hope (1842: 137) to name the unidentified locusts mentioned in Ives (1773: 15). This does not correspond to a species name.

FIGURE 5.9 **Different uses of spiders and beetles on Madagascar. A) *Nephila inaurata madagascariensis* (Golden Orb Spider, Araneidae), known locally as *halabe*, is often eaten as a snack by boys herding cattle or given to children when they are sick. B) Madagascar was the site of a rare attempt to utilize spiders for commercial silk production. In the 19th century, a technical college was founded in Antananarivo where people were trained to farm spiders and spin their silk. The spider-silk-production tradition from this period has not survived. C–E) In Beroboka, a village near the Menabe Antimena Protected Area, children hunt for *Oryctes boas* (Rhinoceros Beetle), keep it as a pet, and consume it as a favorite snack. The wings are removed before cooking. F) Young girls collect small fish and edible insects from a pond near Ranobe in southwestern Madagascar.** (PHOTOS A and C–F by B. Fisher, and B courtesy of Fond Grandidier Library, Antananarivo.)

Aquatic beetles of families Dytiscidae (see Bergsten et al., pp. 1024–34), Gyrinidae (see Gustafson et al., pp. 1034–41), and Hydrophilidae are frequently collected by children while they net small fish in the rice fields (Figure 5.9f). Aquatic beetles are generally eaten as adults and cooked alongside the fish they are caught with.

HEMIPTERA

Etienne de Flacourt, who resided on Madagascar for several years, described planthopper honey, the sweet exudate produced by *Flatida* (Hemiptera: Flatidae) (see Świerczewski and Stroiński, pp. 987–91), in his history of the island (Flacourt 1658 [repr. 1995]: 225, our translation): "There is a kind of sugar which is formed by certain butterflies on Madagascar, on the leaves of a shrub, it is hard and soft like sugar, the inhabitants are fond of it." He goes on to describe the "butterfly" as "an admirable thing to see, that this creature spawns on the bark of the shrub in the form of a black fly whose wing ends are white, and this fly resembles a flower attached to the bark, which after a month detaches and turns into a small butterfly, some of which are red, others green and others yellow, which, for a time, will gnaw at the leaves of this shrub, then after, form this kind of sugar or honey which becomes hard like candy sugar, this sugar is very good for diseases of the lung or a chest cough."

Almost 100 years after these observations, M. Choron from the College de Saint-Denis, La Réunion, submitted a brief report independent of Flacourt's comments on "a new substance from Madagascar" (Choron 1847: 397, our translation): "The raw material resembles manna; it is found on certain trees; the natives eat it and say that it is deposited by a fly which they propose to send to us. I have just learned that the substance contained in the bottle is considered to be a hard gum in the country of Mahafaly, where it is called *tipinder*, and comes from a tree called *maroua* [*maro-hay*?]." Later, Tandrya and Payet (1898) noted that the Mahafaly eat a crystalized sugar deposited by ants on leaves of a tree called "*atembona*." By the 1930s, it had become clear that the "manna" was produced not by ants or butterflies but by a planthopper, *Flatida rosea* (Figure 5.10a) (Decary 1937; Scarone 1938).

FIGURE 5.10 **The consumption of exudates and insect larvae on Madagascar. A) *Flatida rosea* (Flatidae) produces a sweet exudate, known locally as *tantely sakondry*, which is eaten by people and lemurs alike. B–D) Locally known throughout Madagascar as *sakondry*, *Zanna* spp. (Fulgoridae) are among the most-preferred edible insects because they are rich in nutrients and taste like fatty meat. These insects are prepared by washing and then cooking them in their own fat. E) After cocoons of *Borocera cajani* (Lasiocampidae) are removed for silk extraction, the pupae are sold at markets near Itremo. F) Though the domesticated silk moth (*Bombyx mori*, Bombycidae) industry has declined, the larvae are still sold today in markets of Antananarivo.** (PHOTO A by C. Sharp, B and F by B. Fisher, C and D by S. Andrianantenaina, and E by Kew Madagascar Conservation Centre.)

Decary (1937) noted that the Sakalava, Bara, and Mahafaly people are particularly fond of planthopper honey, which they call *tantely sakondry*.

In the field, generally under forest cover, *Flatida* adults can be found clustered along thin branches. They look for all the world like bright red fruits until they shuffle in unison to the back of the twig when an observer draws too close or fly off in a flurry of crimson, emerald, or golden wings. Those who visit later in the year may be even more impressed to discover the larval form mimicking lichen, only with legs. The white, bushy-tailed larvae appear in September to November and prefer plants of the family Combretaceae. Like most hemipterans that feed on plant phloem, *Flatida* excretes excess water and carbohydrates in the form of honeydew: a white, slightly sweet substance, which oozes in droplets and eventually forms masses that may reach the size of a fist on branches or on the ground. Other primates such as *Microcebus* also enjoy this exudate (Joly-Radko and Zimmermann 2010). The insects can produce several times their body mass of honeydew per hour.

The French botanist Perrier de la Bâthie, sensing a business opportunity for a unique food, attempted to farm planthoppers in Combretaceae plantations. He found that the quantity collected was far too small to commercialize (Scarone 1938). Though eating *tantely sakondy* is not strictly entomophagy, it is interesting that some of earliest accounts of insect foods on Madagascar relate to this substance and that there have been attempts to expand production for human consumption on a large scale.

Other Hemiptera noted to be consumed on the island include species of Belostomatidae, Cercopoidea, Cicadidae, Fulgoridae, Naucoridae, Nepidae, and Notonectidae (Table 5.4). In an Antananarivo market, Lacaze (1881) noted baskets full of "aquatic cockroaches" that probably correspond to Belostomatidae; he pointed out that the Malagasy people are very fond of these insects. Decary (1937) noted that nepids are consumed but little appreciated and that he found their flavor unpleasant. During his trip in the Malagasy Region, François Pollen stopped on Mayotte in the Comoros. There, Madame Chaulier, the wife of his host, who was from Madagascar, prepared *Zanna tenebrosa* fried and salted. Madame Chaulier pointed out that she preferred the species from her native soil, which she called *sakondry* (Pollen 1868: 104). Indeed, in many coastal regions of Madagascar, especially in the east, the most preferred insect is *Zanna* (Fulgoridae), locally known as *sakondry* (Grandidier and Grandidier 1908: vol. 4, pt. 3, p. 210; Randrianandrasana and Berenbaum 2015). The genus *Zanna* is widespread on Madagascar (see Constant, pp. 991–93). The characters to differentiate species in this genus are poorly defined, as are their distribution ranges, but all *Zanna* spp. are thought to be consumed by humans.

Hemiptera are prepared by first washing the insects and then placing them in a preheated pan with fat or oil, or in just enough water to cover the bottom of the pot. *Sakondry* (*Zanna* spp.) is the one exception, for like bacon it can be cooked solely in its own fat (Figures 5.10b–d). *Sakondry* is often harvested before the winged adult stage. The wings of adults are sometimes removed before cooking. They are eaten plain with rice or prepared with greens (*ravina*). The taste is similar to fatty meat, which is why they are often referred to in English as bacon bugs.

HYMENOPTERA

The larvae of bees (*Apis* and *Liotrigona*) and wasps (Vespidae) are eaten in eastern Madagascar (Perrier de la Bâthie 1905; Grandidier and Grandidier 1908; Decary 1937; Randrianandrasana and Berenbaum 2015). Since about 2010, companies employing a network of collectors along the eastern coast have started exporting wasp larvae to La Réunion, including a company that managed to ship nine tons in 2014 from the port in Toamasina. One network leader south of Foulpointe who managed a team of collectors reported a decline in availability of larger nests in the secondary forests where they focus their wasp collecting. Collecting such large quantities of a predator may have unintended impacts on local forest communities. This critical question needs to be investigated. The larvae of Hymenoptera can be eaten raw but are most often cooked—after being removed from their cells, they are boiled in water and sautéed in a pan.

LEPIDOPTERA

Lepidopterans consumed on Madagascar include the larvae and pupae of what tend to be larger species reared or collected for the local silk industry. This food preference is especially common in the Central Highlands, where wild silk production is traditionally practiced in tapia woodlands (see Kull and Birkinshaw, pp. 121–27). Other lepidopterans consumed across Madagascar are those that are seasonally very abundant, such as *Latoia* (Limacodidae) and *Hypsoides* (Notodontidae).

Flacourt was the first to bring the attention of the Western world to the diversity of silk used on Madagascar. Of the four types he mentions, three can be associated with species consumed today:

> Silkworms, there are four kinds, namely: 1) those which produce a single shell as in France, except that it has small thorns which we call *landevé* and 2) those which produce small shells wrapped in a large one, in which there will sometimes be more than five hundred, which is called *landesaraha*; 3) those who make their silk in the *anacau* tree which is a tree on the seashore like the cypress. These hulls are the only ones hanging from a small web and filled all around with small fetuses of leaves of said tree. This silk is the finest and strongest of all, it is called *landeanacau*; and 4) those who make their silk in the *vontaquier*, which is in small shells alone, the silk is very fine, it is called *lande vaisaqua*. (Flacourt (1658 [repr. 1995]: 225; our translation)

The moth species responsible for the first three kinds of silks are 1) *Borocera madagascariensis* (*landevé*, Lasiocampidae), 2) *Hypsoides* spp. (*landesaraha*, Notodontidae), and 3) *Deborrea humberti* (Psychidae) with its host plant *Casuarina equisetifolia* (*landeanacau*, Casuarinaceae). However, the *lande vaisaqua* moth, which uses the host plant *Strychnos spinosa* (Loganiaceae), has yet to be identified.

Flacourt (1658 [repr. 1995]: 225) goes on to note that (our translation) "on the Isle of Sainte Marie, there is a quantity of silk, which the natives do not know how to spin; they throw it out and eat the pupae inside." He was likely referring to *Hypsoides radama*. Coquerel (1855b: 25) also noted this species was abundant, produced a beautiful strong silk, and that the locals on Ile Sainte Marie discarded the cocoons after eating the pupae inside. A similar

practice continues today in the uplands of western Makira, where the young pupae of the silk moth *Ceranchia apollina* (Saturniidae) are collected by the Tsimihety solely for consumption (M. Ratsimbazafy, unpublished data). These two examples suggest that silkmoth pupae are sometimes valued solely as food.

After Flacourt, we next see a mention of silk by S. Dubois (1674: 147) during his travels to Madagascar between 1669 and 1672, where he marveled at the diversity and beauty of silk produced by local people. W. Ellis (1858) noted that the Betsileo collected a pupa enclosed in a very hard, ovoid cocoon the size of a small olive, strongly stuck to the branches of the tapia tree. He described the species as being very good to eat and sold in large quantities in markets. Ellis's description matches the silk moth *Latoia albifrons* (Limacodidae). Vinson describes the consumption of the same species in detail:

> There is a very curious little caterpillar, very plump and white with rows of spikelets of short, silky hairs; it gives birth to a chocolate-colored butterfly with a small cluster of white and green spots on the inner and upper part of the wings. But before reaching this perfect state, the caterpillar weaves an oval cocoon, hazel-colored and quite resistant, against a small branch: on the surface of the cocoon, there is a small groove for implantation against the branch that supports it. We open this little shell, in the middle of which the white, swollen, and fatty caterpillar shows itself like an almond in its envelope. (Vinson 1863c: 45; our translation; also see Vinson 1865: 309)

Vinson felt the flavor and texture of *L. albifrons* pupae to be quite adaptable to French cuisine (our translation): "Many of these white larvae are collected which have the appearance of curdled milk. They are fried in oil with a little grated cheese and a few egg yolks and rolled in a pan. It is a delicious dish, having the appearance of a dish of veal brains au gratin, only, it is more delicate, it is a dish of prince and nobleman in Antananarivo" (1863c: 45; 1865: 309).

Borocera cajani, or *landibe*, is the most important wild silk moth for the silk industry on Madagascar. The people of the Central Highlands have a long tradition of using this species to produce silk shrouds, as well eating the insects. They still use its silk to produce textiles today. The species is endemic to Madagascar and broadly distributed on the island, colonizing the host plant *Uapaca bojeri* (Tapia; Phyllanthaceae), of the Central Highlands. In the silk and edible-insect literature this species has been confused with *B. madagascariensis*, which is also consumed but is more abundant along the coastal portions of the island (Razafimanantsoa et al. 2012). Vinson (1863d) was impressed with the strong and beautiful silk from the wild silk moth. He admired the zero-waste model where cocoons are used for the silk industry while the pupae are consumed (Figure 5.10e). These pupae were served at the table of Radama I (Pfeiffer 1861) and were the treats eaten by the son of Radama II in the introduction.

Decary (1937) provides further details about *B. cajani* pupa preparation. After being killed in boiling water, they were fried or sometimes just cooked under ash. To further emphasize their gastronomic appreciation, in 1894, a dish of *Borocera* pupae prepared with béchamel sauce (white sauce made with cream and flour) was served at an official meal at the French governor's residence in Antananarivo.

Osborn also noted the favorable taste of silk moth pupae:

> The silkworm in the chrysalis stage is as much esteemed for food as the locust and these also are to be found in the markets and in well-provisioned homes. I saw more silkworms in the markets of the Betsileo country than else-where and especially in the region about Imamo. There was no dearth of them through Imerina, but in most places not so many as in Imamo, for here the tapia tree is autochthonous and plentiful. This is the food of the Madagascar silkworm and they are to be found in large numbers where it flourishes. Not at all second to the silkworm and the locust and grasshopper is a kind of big, fat, sweet spider. Once I had a delicious stew made from spiders, locusts, silkworms, grasshoppers, fish, manioc meal, rice and suet. When I ate it for the first time I did not know what it was made of, but fuller information did not prevent my enjoyment of the bug and worm stew several times afterwards. (Osborn 1924: 325)

The cocoons of *Borocera* are often collected by children, especially during the winter, when parents are occupied with agricultural work (Barsics et al. 2013a). The pupae accompany rice and are eaten soon after harvesting, unlike dried locusts, which can be stored for later use. The pupae are prepared for consumption by removal from the cocoon, after the plucking of the irritating hairs, which are more abundant in young pupae. The pupae are then washed, and a slit is made on the head to facilitate cooking. Though sometimes fried directly after washing, they are more often simmered in water for an hour, when salt and oil are added. Sometimes pupae are dipped in oil before cooking.

Decary (1931: 289; 1937: 171) wrote that he could find huge quantities of scalded pupae of *Deborrea malgassa* (Psychidae) with cocoons removed. Known locally as *fangalabola*, these pupae were sold in the markets of Antananarivo. This species can become locally abundant and can be a serious pest in forest plantations (Grubenmann and Madle 2016). Barsics et al. (2013b) noted that the tradition of feeding *D. malgassa* to children who wet their beds is still practiced today.

Members of the genus *Hypsoides* can also be abundant, a characteristic that people take advantage of to harvest these insects for food. In the north of the island, individuals of *H. diego* group together to pupate in a single large pouch. This species is highly sought after as food by the Antakarana. Special taxonomic attention was given to the *Hypsoides* of Madagascar because of their potential to replace *Bombyx mori* (Bombycidae) in the Malagasy Region. *Hypsoides diego* produces a finer silk than *B. mori* and is better adapted to the climate on Madagascar (Coquerel 1855a, 1855b).

There are also records of people consuming the larvae of moths in the families Saturniidae and Sphingidae. Younger pupae are preferred because older pupae can taste bitter. Barsics et al. (2013a) discussed two saturniid species in the Itasy area: *Bunaea aslauga* (*sarohy*) and *Maltagorea fusicolor* (*bokana*). As with *Borocera*, children collect the larvae while adults are busy working in the fields. The larvae are eaten with rice. While several different methods of preparation are known, all begin by emptying the larva's digestive tract. The body is first pressed lengthwise, from the head to the anus, to extract the excrement, then flattened in the other direction to evacuate any undigested plant material. Cooking methods include grilling for five minutes on hot coals or boiling in water after

using a stick to turn the larvae inside out. After boiling for up to one hour, salt and oil are added. Alternatively, instead of boiling, the larvae can be fried or sautéed once turned inside out. *Maltagorea fusicolor* is prepared in the same way but is not necessary to turn inside out. Limacodid pupae are also eaten and prepared in a manner similar to that for other pupae, except that the incision in the head is not necessary. Harvesters are mostly children and the pupae are considered tastier than those of *Borocera*.

Even pupae of the introduced, domesticated silk moth *Bombyx mori* are eaten on Madagascar. Because Madagascar had already developed a silk tradition based on wild native lepidopterans, early Western visitors saw the island as a potential contributor to the global silk trade. The first attempts to improve the quality of silk produced on Madagascar involved selecting improved strains of *Borocera* and by employing spider silk (Fee 2013). There were even earlier calls to introduce *B. mori* to the island. For example, when Mayeur was in Madagascar (1758–1787) and did not observe *Bombyx* sericulture in Imerina, he strongly recommended introducing it (Mayeur 1913b: 41). Instead, the silk was initially imported as floss from Oman (Fee 2013).

The first introduction of *B. mori* appears to be around 1815, when the British governor of neighboring Mauritius, James Hastie, encouraged King Radama I to make *Bombyx* weaving an income generator for the Merina crown. James Hastie sent mulberry bushes (*Morus*, Moraceae), silkworms, and reeling machines, as well as Bengali convict-laborers to instruct the local people on technical aspects (C. Anderson 2000). After King Radama's death, *Bombyx* sericulture quickly collapsed as a state enterprise. However, the techniques spread to Merina villages and improved over time. Newer varieties of mulberries and silkworms were introduced by Jean Laborde in 1850 and by the sericulture service at the Nanisana agriculture station. These latterly introduced European breeds are still used in recent times (Prudhomme 1905). Along the way, *B. mori* was adopted as a food source across the Central Highlands; the larvae are still sold today in markets in Antananarivo (Figure 5.10f), such as at Mahamasina, where the pupae are sold next to shrimp at the same price as the crustaceans.

ODONATA

Dragonfly larvae are collected along with other aquatic insects and small fish year-round from rice paddies or streams (Decary 1937; Barsics et al. 2013a; for information on the order Odonata in Madagascar, see Dijkstra, pp. 953–63). Larger species such as those of the genus *Anax* (Aeshnidae) can be collected in marshes and rice fields. The legs are often removed before cooking on coals or frying.

ORTHOPTERA

Humans have long been awed by natural phenomena showcasing the abundance of life, from islands filled with penguins in the South Sea to migrating wildebeest in the Serengeti. The spectacular locust migrations that periodically invade Madagascar, however, are often met with shock from visitors, who see these clouds of insects as potential destroyers of crops in their path. Yet locusts also provide the Malagasy with a valuable food staple, as noted by some early observers. The arrival of locust swarms was even celebrated in the extreme south, which suffers from seasonal food insecurity. It is worth noting that even through literature accounts tend to focus on the periodic swarms, the same species of locust, along with many other orthopteran species such as *Brachytrupes membranaceus colosseus* (*sahobaka*; Figure 5.11a), are collected and consumed throughout the year (Van Itterbeeck et al. 2019). Here we review some of the principal accounts that show the historical magnitude of locust swarms, the use of locusts as a food source, and preparation methods for these insects over the past 400 years.

Locusts: Devourers and Great Providers

The first mention of locusts on the island comes from the Jesuit priest D'Azevedo, who on 23 May 1617 noted in a letter that people in the Menabe area of central western Madagascar eat dried insects and are extremely fond of eating locusts (Grandidier and Grandidier 1904: vol. 3, p. 243). Shortly afterward, in 1625, the skipper Willem Ysbrantsz Bontekoe, after arriving in the Manafiafy Bay north of Tolagnaro, described how locals captured locusts, removed their wings, and grilled them (Bontekoe 1663).

A more detailed account comes from François Martin in 1665 (Martineau 1931). He recounted the difficulty of finding rice during his travels on the east coast that year because locust swarms had destroyed the crop. He described witnessing locusts arriving to wreak incredible damage over the course of three days. He noted the swarm began to fly immediately after sunrise, stopped at sunset, and inflicted the greatest damage on fields where it spent the night. "The rice, which was very beautiful and whose harvest was near, was all lost. ... a damage one cannot imagine, unless one has witnessed it" (Martineau 1931: 129).

The devastation that locust swarms caused to crops, and the fact that locals consumed the locusts, was noted again in 1709 by Adrian van Broeck of Pirate Avery fame (van Broeck 1709). Avery's account was bolstered by Dr. Edouard Yves (Ives 1773: 15; Grandidier and Grandidier 1907: vol. 5, p. 267), who anchored in July 1754 at Saint Augustine Bay near Toliara. He proclaimed that the most extraordinary thing on the whole island was the sheer number of locusts he saw, which rose from the ground like thick clouds. He also noted that the locals preferred eating them to the best fish, frying them in oil after removing legs and wings. Charpentier de Cossigny in 1773 (1799: 358) described the locals' enjoyment of consuming locusts as on a par with seafood, and compared the taste to crayfish. He noted that when the insects were prepared by grilling on hot coals they turned reddish, a sign that they were ready to eat.

The accounts so far have noted the widespread consumption of locusts and the simple preparation methods. With Nicolas Mayeur in 1785, we begin to understand the importance of this food for the Malagasy people (Grandidier 1896a: 556, 1896b: 14–15; Mayeur 1913b: 32). Mayeur lived on Madagascar for about 30 years (1758–1787) and spoke Malagasy so fluently that he served as an interpreter at French government outposts on the northeastern coast. He described the arrival of a locust swarm during a fight between two tribes not far from Antananarivo along the banks of the Ikopa River near Alasora. The two tribes, with 12,000 soldiers, had been

FIGURE 5.11 **The consumption of different forms of the order Orthoptera is widespread on Madagascar. A) *Brachytrupes membranaceus colosseus*, locally known as *sahobaka*, for sale at a market near Ambanja. This is the largest cricket sold for consumption on Madagascar. B–D) *Locusta migratoria* (Acrididae), known locally as *valala*, is collected at Ranobe, north of Toliara, and prepared in a manner similar to that of other large orthopterans: the legs and wings are removed and the insects are fried in oil. They turn pink when ready to eat. E–F). Native cricket species of the genus *Gryllus* (Gryllidae) offer an opportunity to create small-scale and low-impact food production. The generic name, *Gryllus* ("grill us"), seems an invitation to cook them (Simmonds 1859).** (PHOTO A by F. Rajemison, and B–F by B. Fisher.)

fighting for 10 days. One side had received reinforcements of 3000 men and had just begun to march to secure victory when an immense cloud of locusts suddenly obscured the sky and settled upon the surrounding rice fields. The firing ceased immediately as soldiers from both sides rushed out to collect the insects. The women, children, and older men came out of hiding and joined the collecting, resulting in no fewer than 20,000 people crawling on all fours and busily engaged in catching this prized source of food. When questioned as to why the war was suspended with the arrival of the locusts, the king responded to Mayeur that while a war is most often of interest only to those who declared it, locusts are of interest to everyone.

This excitement at catching locusts probably reflects the importance of the insect to a household for its food security and also as a chance to earn income by selling the insects, in the form of dried or fried products. Locusts were not just consumed in the countryside but also sold in cities. Ellis visited Madagascar three times between 1853 and 1856. He described his horses being spooked by swarming locusts so numerous they resembled falling snow. "The women and children rush[ed] out with great clamor and endeavor to collect locusts using cloth (*lamba*) and baskets" (W. Ellis 1858: 211). They detached the legs and wings by shaking them from one end to the other of a long sack. The legs and wings were then winnowed away (an observation also reported earlier by Leguével de Lacombe and de Froberville [1840]), and the bodies were dried in the sun or fried in fat. Some were kept in sacks for food, and some sent to market in Betsileo and southward. Vinson (1865: 302) noted that on the steps of downtown Antananarivo, large baskets containing millions of dried locusts from three different species were for sale. He mentioned that locusts were common, highly sought-after foods. Similar observations of baskets containing locusts in Antananarivo markets were regularly reported by other authors (e.g., Lacaze 1881: 67; Perrier de la Bâthie 1924). Locusts were also observed in other markets: in 1863, James Sibree noticed great heaps of brown locusts for sale in the Betsimisaraka market in Toamasina.

Sibree (1884) described an encounter with a swarm on his way to preach in Analamahitsy, then on the outskirts of Antananarivo, on the afternoon of 21 September. He too compared the arrival of the

locusts to a heavy snowfall, except the ground was not white. People were busy gathering the insects in baskets, and every child and adult he passed had a dozen or more locusts impaled on a straw for that night's dinner. Sibree (1915) mentioned that for a few days after each swarm, great brown heaps of locusts were seen at all the roadside shops. The locals describe the taste as akin to shrimp without any insides.

Camboué (1886) devoted an entire publication to the locusts of Madagascar. He noted that locusts are both a curse and a blessing on the country, both ravaging crops and serving as a resource for people to feed themselves and their domestic animals. He describes the preparation as follows: locusts were first boiled in large pots then laid out on large mats in the sun to completely dry, after which their legs, wings, and head were removed, and finally they were crushed into powder or stored whole for local consumption or to supply markets. He noted that once ground and dried, locusts could be kept for a very long time. For eating, they could be flavored with chili and salt or, even better, fried in fat. They were also boiled or cooked with chicken or beef to be eaten along with rice. Locusts could also be used to make broth, or *ro*, to accompany rice. Several authors noted that locusts were a food not only for the poor but for different strata of Malagasy society. Locusts were one of the delicacies served during the endless banquets given by Queen Ranavalona I (Pfeiffer 1861). Camboué noted that (our translation) "at the Tananarive palace, the royal table itself, which prides itself on progressive ideas, also serves them. The late queen of the Hovas, Ranavalona II, who had her hunters secure the best game from the forest, her fisherman to bring her the best fish from lakes and rivers, had women who scoured the countryside specifically to collect precious Orthoptera for her table" (Camboué 1886: 169–170). Camboué remembered that when Queen Ranavalona III was on an official visit to Ambohipo outside of Antananarivo with her husband, Ratrimo, she chased and gathered up locusts to take home to prepare for dinner. He also noted that many species of locusts were eaten, but not the large, colorful *valalanamboa* (*Phymateus saxosus*). Camboué pondered whether orthopterans could be developed as a food source for humans or at least for animals. He pointed out that grasshoppers have been eaten since antiquity and were recorded in Leviticus as a food source for the people of Israel. Preparations of locusts were relayed by Grandidier and Grandidier (1908: vol. 4, pt. 3, p. 208), who noted the enthusiasm of people across Madagascar for eating the insects.

Osborn's account includes one of the most colorful descriptions of both Malagasy locust-catching methods and how local people prepared them to sell or consume later (Osborn 1924). Importantly, he realized that the gathering of locusts was a means to secure a food supply for the lean months. He proclaimed that, thanks to locusts and other edible insects, there was no famine on Madagascar and that because of edible insects there was little worry over the question of food. Osborn summed up the central role of locusts in the local diet in this way: "All forward looking housekeepers in Madagascar have a goodly supply of dried locusts on hand" (Osborn 1924: 324). Collecting locusts, he found, was done mostly by women and children, who trapped the insects in flight by scooping them up in large baskets and on the ground by sweeping them into shallow depressions. He noted they could also be found in public markets, where they were sold in hundreds of huge, shallow baskets.

Decary (1925) noted that in the extreme south of Madagascar, a region prone to drought and famine, the Androy people celebrated the arrival of locusts as an essential source of food. In the Central Highlands, even though locusts can devastate rice fields, they were also collected to eat and sell, and as feed for pigs. The Androy, he wrote, ate dried locusts raw after removing the legs and wings. In 1925, while traveling in the southeast, he saw mats of drying locusts and described a chief giving a hat filled with locusts to his porters, who quickly finished off the treat. Decary also noted that locust commerce occurred across Madagascar. Locusts were given a high-speed transportation fee on the railway and were taxed at the same rate as game and fish. Decary (1925, 1937) also described how preparations differed among different species of locusts. Smaller species (*tsibody*) were cooked by placing them on hot ash until their abdomens burst. For larger locusts, two principal methods were employed. The first involved grinding the insects until they resembled powdered tobacco, then cooking them in water and eating them as a sauce (*laoka*) with rice. In the second method, the wings and legs were removed; the insects were then soaked for half an hour in salt water and finally fried in fat (Figures 5.11b–d). This second dish was most popular in the Central Highlands and appeared on princely tables, as described above. Drying locusts and grinding them into a powder eases both long-term storage and transport.

ARANEAE

The consumption of spiders might have been overlooked by early visitors to Madagascar if not for the popularity of their silk. These Europeans were keen to note any local resources that could be exploited commercially and considered the island's spiders a promising source of this valuable commodity.

While Vinson was on Madagascar for the coronation of Radama II in 1861, he also found time to study the island's spiders. He was the first to describe the consumption of *Nephila inaurata madagascariensis* (Golden Orb Spider), known locally as *halabe* (Figure 5.9a). Vinson noted, as Decary (1937) did later, that *Nephila* would be fried in oil or fat. Vinson was also the first to describe the impressively strong silk spun by this spider. He suggested that the silk might be of commercial use and value (Vinson 1863a: 193). Osborn (1924: 325) found spiders to taste sweet in a stew he was served. A number of large *Nephila* species are native to Madagascar and all are likely eaten by people. Barsics et al. (2013a) recently noted that young boys are the main consumers of *Nephila*, which they encounter while herding zebu. Further, some adults also consume spiders because they find this food boosts energy, and adults may also give grilled *Nephila* to their children when they are sick.

Though there are many ecological concerns with eating predators such as spiders or wasps, past efforts to farm spiders to produce a finer, glossier silk fiber provide insights into the feasibility of large-scale spider production. Building on Vinson's suggestion, Jacob Paul Camboué, a French Jesuit missionary and naturalist, began experimenting in the 1880s and 1890s with ways to extract the silk directly from the spider. This continued with French colonial administrator Nogué, who thought silk production could be a unique export for Madagascar. To support that effort, he created a

hand-powered machine that could spin the silk from the live spiders while causing no harm to the arachnids. In the 19th century, a technical college was founded in Antananarivo where people were put to work to collect and spin silk from spiders raised in special gardens (Figure 5.9b). The spiders were periodically taken from their webs in the garden, then placed in special racks to enable silk to be drawn from their spinnerets and wound on a reel. The animals were later released back to the garden to recuperate (Petrunkevitch 1921), as excessive production of silk from a spider without recuperation would kill the animal. The silk produced by this spider was finer, lighter, and stronger than silk derived from the domesticated silkworm. Beautiful garments of high quality were even produced for the Paris Exposition in 1900. Unfortunately, the difficulties of procuring live insect food for these spiders made the use of their silk economically unviable, and attempts to farm them ended.

Though farmed spiders require a food source, it may be possible to sustainably harvest them for silk production. Textile maker Simon Peers, based in Antananarivo, demonstrated this when he captured and released over 1 million spiders in Antananarivo over a five-year period, using modifications of the technology developed by Nogué to harvest their silk. The resulting cloth is a testament to the beauty of this unusual silk (Morgan 2016).

FUTURE DIRECTIONS

Edible insects have a 400-year documented history on Madagascar. Most of the insects mentioned historically are still eaten today and prepared using similar methods. Their persistence in the Malagasy diet is a testament to their good flavor and value as food. There is growing interest in farming insects as an environmentally sustainable and nutritious alternative to traditional protein sources (van Huis et al. 2013). Insects reproduce quickly, have high growth rates, and are far more efficient at converting feed into body mass than mammalian livestock. The feed conversion of house crickets is estimated at twice that of chickens, four times that of pigs, and more than 12 times greater than that of cattle. This high conversion rate also means insects require much less water and cause far fewer environmental impacts per unit of protein produced. They are also valuable sources of minerals and vitamins essential for human development (Bednářová et al. 2014; Payne et al. 2015, 2016). In fact, the locusts that attack crops in southwestern Madagascar probably contain more iron than do the crops themselves (B. Fisher, unpublished data). Additionally, insects are ideal for small-scale community development projects because they are small, easy to breed, and require minimal investments in capital and land. Minimal investment and scalable farm modules make insect farming accessible to marginalized groups, enabling women and the rural poor to produce their own food and improving global food security (Figures 5.11e and f).

The farming of insects for food and animal feed has been increasing in continental Africa and Asia (van Huis 2020) and is both culturally and nutritionally relevant on Madagascar. Importantly, insect farming on the island should be restricted to species already present on the island, since introduction of new species could harm the native environment and/or human cultures. Though early attempts to farm *Flatida* planthoppers and *Nephila* spiders were not successful, other invertebrates present on Madagascar offer promise for large-scale farming. However, some of the most obvious candidate species may not be appropriate for large-scale propagation: locusts such as *Locusta migratoria* are highly allergenic and trigger occupational allergies among farmworkers in closed facilities (Burge et al. 1980; Lopata et al. 2005) and could represent a threat to culture in open-air farms.

Selecting species suitable for large-scale farming is therefore not a trivial task. The species presented in Table 5.4 should be evaluated to assess their suitability for commercial-scale farming. Such an analysis could include an evaluation of biological cycles, nutrient content, and other variables that affect environmental health and farming costs. It would also be important to survey local attitudes toward insect consumption to ensure the program is suitable for local markets. Insect farming offers great potential to help Madagascar to address development issues such as population growth, food security, climate change, diminishing water resources, child nutrition, and persistent poverty. By providing a protein source requiring little energy input yet offering high feed conversion rates, insect farming could help reduce bushmeat and beef-product consumption. With increased food security, forest conservation becomes more possible.

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