CHAPTER

11

Insects as Human Food

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INTRODUCTION

The eating of insects is not very common in Western countries, while in the tropics insects are often a regular part of the diet. By consulting the scientific literature on insects as food and feed worldwide, Jongema (2015) listed more than 2000 different arthropod species. They belong to the following groups: Coleoptera (beetles, often the larvae) (31%), Lepidoptera (caterpillars) (17%), Hymenoptera (wasps, bees, and ants) (15%), Orthoptera (crickets, grasshoppers, and locusts) (14%), Hemiptera (true bugs) (11%), Isoptera (termites) (3%), Odonata (dragonflies), Diptera (flies), and others (9%).

Why is the eating of insects largely limited to tropical countries? There are several reasons. First, edible insect species are available throughout the year, while in temperatezones during the winter period they are in a resting stage, called diapause or quiescence. Second, insect species in tropical zones are larger probably because insects respire through a complex network of tubes (called the tracheal system) that delivers oxygen-containing air to every cell of the body. With higher temperature the diffusion of oxygen is faster, shown by the gigantic insect species during the Permian era (about 290 million to 250 million years ago); besides oxygen levels were much higher than at present (Harrison et al., 2010). Third, tropical insect species are often aggregated facilitating harvesting, such as caterpillars of *Imbrasia* spp. or locust swarms. Also the future queens and kings of termites (the reproductives) swarm at the first rains after the dry season (their nuptial flights). Four, people are closer into contact with nature, because the weather permits people to live outdoors, although urbanization in tropical countries is countering this effect. In Africa this will increase from 40% in 2014 to 56% in 2050 and in Asia during the same period from 48% to 64% (UN, 2014). Five, Westerners do not value insects very much and often regard them as dirty, disgusting, and dangerous (Looy et al., 2014). The main argument however is that it is easier to harvest a meal of insects from nature in warmer regions than in temperate zones.

Another explanation why insects were never domesticated in the West was given by DeFoliart (1999). He stated that historically insects were

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not competitive as food items. Agriculture originated mainly in the fertile crescent of the Middle East, where crops such as wheat, barley, and several legumes were first grown and animals such as sheep, goats, pigs, and cattle were first domesticated (Diamond, 1997). Insects in the Middle East were of minor importance.

A number of authors have given an overview of the eating of insects in different continents in particular (Bergier, 1941; Bodenheimer, 1951), and DeFoliart (2012) in his online bibliography. Evans et al. (2015) explain the term "entomophagy" in a historical context. They indicated that the term was mainly used by people who do not eat insects, denoting a peculiar eating habit from other cultures. An example is the title of the book of Bergier (1941) "*Entomophagous People and Edible Insects*" (translated from French). A historical overview of edible insects was also given by Costa-Neto and Dunkel (2016).

An overview of the practices of harvesting and eating insects in different parts of the world will be given. For early hominids, it was probably an important part of the diet. I will indicate the difficulty of the taxonomic identification of species as often vernacular names are used. Some examples are given of how important insects are in the diet and pharmacopeia of people. There are taboos which prevent people from eating insects. I will give examples of ingenious harvesting practices showing people's intricate knowledge about the biology and ecology of insect species. This knowledge about eating insects now seems to benefit Western countries as it is increasingly realized that using insects either as human food or animal feed offers considerable environmental benefits.

HISTORY

McGrew (2001) showed that in early hominid diets, insects were the only kind of invertebrate food eaten by primates across species from tree shrews to humans as they are nutritious and abundantly present. Four of the main five insect groups eaten (Coleoptera, Lepidoptera, Hymenoptera, Orthoptera) (McGrew, 2001) were the same as the grouping made by Jongema (2015), who, however, listed the fifth group Isoptera (termites) in the sixth place. Backwell and d'Errico (2001) gave evidence that foraging for termites as food was practised by early hominids for nearly a million of years in South Africa. They did so by studying the wear patterns on bones used as a tool by *Australopithecus robustus* to dig termites from mounds.

Madsen and Kirkman (1988) concluded from ethnographic, ethnohistoric, and archeological data that insects may have been major components of meals in the Great Basin in the United States. They studied the lakeside cave at the margin of the Great Salt Lake. Apparently during plagues, probably occurring at least once every 2 years, the grasshopper *Melanoplus sanguinipes* (Orthoptera: *Acrididae*) had flown or was blown into the lake, resulting in salted and sun-dried grasshoppers, tens of kilometers along the beach. The densities were estimated to range between 1800 and 24,000 per meter. Deposits, such as coprolites in the lakeside cave, suggested that 4500 years ago, these grasshoppers were collected on the beach, winnowed in the cave, and consumed. Because of the salt, the grasshoppers were naturally preserved, and as such could be eaten for several years. Prehistoric human coprolites with chitinous exoskeletons of insects were also found in other places of the United States (Arizona, Arkansas, Colorado, Texas, Kentucky, Missouri, Nevada, Utah) and in Mexico and Peru (Brothwell and Brothwell, 1998, pp. 67–72; Reinhard and Bryant, 1992). However, these may not have been all dietary components, as there is a possibility that they were remains of coprophagous insects or that insects were eaten accidentally. However, the amount present in coprolites suggest that they were eaten as food.

Silk was produced in China around the fourth or the fifth century BC (Vainker, 2004). However, it is not sure whether at the time the cocoons were already eaten. Mitsuhashi (2008) mentions that in the Shanxi province in China, cocoons of the wild silkworm, *Theophila religiosae* (Lepidoptera: *Bombycidae*), were found 2000 to 2500 years ago with large holes in them suggesting that they were eaten. It is likely because the cocoons are put in hot water to prevent the moth from escaping and ruining the silk, and so the cooked pupae could have been eaten. So, the silkworm served two purposes: sericulture and food. Such as double production purpose may also be the case for honey, which is often eaten together with the bee larvae (Ghosh et al., 2016; Hocking and Matsumura, 1960).

According to Sutton (1995), anthropologists seem often unaware of the important role of insects in food history, and the reasons are the Western bias against insects (DeFoliart, 2012), the generally low "visibility" of insects in archeology (Madsen and Kirkman, 1988), and the overemphasis on mammals and hunters (Kornfeld et al., 1996).

NOMENCLATURE OF EDIBLE INSECTS

One of the difficulties in knowing which insects we are dealing with are the vernacular names. For example, ants of the genus *Atta* and *Acromyrmex* (Hymenoptera: *Formicidae*) in Peruvian forests have up to 12 different names depending on the locality, their instar, or the castes (Dourojeanni, 1965). A very clear example about the confusion caused by common names is the term "white ants" which is very often used for termites, while ants (Hymenoptera) are from a complete different order than termites (Isoptera). This is also exemplified by the book *Soul of the white ant* (Marais, 1973), which actually deals with termites. In New Zealand, The Maori called the larvae of a large hawkmoth *Agrius* (=*Sphinx*) *convolvuli* (Lepidoptera: *Sphingidae*) "Anuhe" (Miller, 1952). This is a foliar pest of the sweet potato and has 20 other synonyms. The same name was, however, used for the edible larvae of the ghost moth *Aenetus* (=*Charagia*) *virescens* (Lepidoptera: *Hepialidae*) which lives for the first 5 to 6 years in tree trunks.

Yen et al. (1997) did a study in Central Australia on the use of vernacular names of insects with the aboriginal group Anangu, who speak Pitjantjatjara. They have no general name for insects or invertebrates. Edible grubs are called "Maku." However, it depends on which part of the host plant they are found. Grubs from the river red gum, *Eucalyptus camaldulensis*, have different "Maku" names depending on whether they are derived from the roots or the trunk or the branches. Moreover, there are at least 24 other Maku names depending from which host plant they are harvested. In Australia the term "witchetty grub" or "bardi grub" can denote a large, white, wood-eating larvae of particularly the cossid moth *Endoxyla leucomochla* (Lepidoptera: *Cossidae*), which feeds on the roots of the witchetty bush. However, the term may also apply to larvae of other cossid moths, ghost moths (*Hepialidae*), and longhorn beetles (*Cerambycidae*) (Wikipedia, 2016).

Costa Neto and Ramos-Elorduy (2006) list a considerable number of edible insect species from Brazil, but they are also confronted with the difficulty of converting vernacular names to scientific ones.

In the Sahelian region many grasshopper species are eaten (Van Huis, 2003). De Groot (1995) found that by showing pinned preserved grasshopper specimens to subsistence millet farmers in Niger that women knew more grasshopper species by their vernacular names than men because they had to harvest and cook them. The Mofu-Gudur is a Sahelian ethnic group in the extreme north of Cameroon. They could identify 65 different grasshopper species with local names: large ones 15 (of which 13 are edible); small ones 41 (36 edible); not classified 9; mantids 8 (5 edible) (Barreteau, 1999). This means that almost all species are considered edible. If not, the name often reveals it, for example, *Humbe tenuicornis* (Orthoptera: *Acrididae*) meaning "the one that pierces the neck." The names reflect the following: (1) whether "they are males or females (the nutritious females are more appreciated); (2) their life cycle, distinguishing larvae from adults; (3) their host plant or host tree; (4) characteristics, for example, from a culinary point of view (fat, meager, or toxic such as *Zonocerus variegatus* (Orthoptera: *Pyrgomorphidae*) although this species is eaten as well), color, form, brightness (light from white millet, or reddish from red millet); (5) environment, for example, desert or riverine, or dry and rainy season; (6) others, for example, a species that when eaten or even touched will cause swollen breasts and cut milk delivery. In central Mexico, the Pjiekakjoo name the invertebrates according to physical characteristics such as similitude with animals, fruits, and tools; properties when cooked; and hardness, ethology, and ecological traits (Aldasoro Maya and Gómez, 2016).

FIGURE 11.1 Edible insects with the bamboo caterpillar, *Omphisa fuscidentalis* (Lepidoptera: *Crambidae*), in the front, Tlat Dong Makkhai Market near Vientiane, Lao People's Democratic Republic. *Photo: Arnold van Huis.*

IMPORTANCE OF EDIBLE INSECTS IN DIETS

Most insect species that are collected from nature are seasonally available as they depend on the host plant or host tree. That is why on the diverse vegetation in the mountainous regions of the Lao People's Democratic Republic (Lao PDR) a broader variety of insects are available than on the Vientiane plain (Nonaka et al., 2008). In the northeast of Lao PDR, especially in the rainy season of June and July many species of insects can be harvested, such as termites, crickets, and beetles, while in the dry season only bamboo caterpillars (Figs. 11.1 and 11.2) and dragonflies are available (Hanboonsong and Durst, 2014).

FIGURE 11.2 Vegetables packed with the bamboo caterpillar, *Omphisa fuscidentalis* (Lepidoptera: *Crambidae*), Tlat Dong Makkhai Market near Vientiane, Lao People's Democratic Republic. *Photo: Arnold van Huis.*

Some insects species in Lao PDR are available throughout the year, and these are often aquatic ones, such as the giant water bug, *Lethocerus indicus* (Hemiptera: *Belostomatidae*), (Figs. 11.3 and 11.4) or the water scorpion *Laccothrephes* sp. (Hemiptera: *Nepidae*) (Nonaka et al., 2008). The Asian weaver ant *Oecophylla*

FIGURE 11.3 Overview of edible insects for sale with the giant waterbug, *Lethocerus indicus* (Hemiptera: *Belostomatidae*), on the left-hand side, Tlat Dong Makkhai Market near Vientiane, Lao People's Democratic Republic. *Photo: Arnold van Huis.*

FIGURE 11.4 Giant waterbug, *Lethocerus indicus* (Hemiptera: *Belostomatidae*), Klong Toey Market, Bangkok, Thailand. *Photo: Arnold van Huis.*

smaragdina (Hymenoptera: *Formicidae*) is one of the most favored edible insect species in the Lao PDR and Thailand and what is eaten is the queen brood (large larvae and pupae) (Fig. 11.5). The queen brood is collected from February to April, and erroneously called "ant eggs" indicating that they are not aware that the larvae and pupae develop into future queens (Van Itterbeeck et al., 2014).

FIGURE 11.5 Pupae of the weaver ant, *Oecophylla smaragdina* (Hymenoptera: *Formicidae*) on a heap of ice, Klong Toey Market, Bangkok, Thailand. *Photo: Arnold van Huis.*

In the Sahelian region certain grasshopper species are not eaten during the rainy season as they have a bad taste, but are appreciated during the cool part of the dry season when the harmattan is blowing (Seignobos et al., 1996).

It is difficult to indicate how important insects are as food in tropical regions, because the food source is seasonal. In Africa, in some parts of the Central African Republic it was estimated to be 15% of the meat diet (Roulon-Doko, 1998) and in some parts of the Democratic Republic of Congo 10% (Gomez et al., 1961); see also Van Huis (2003). In the Delta region in Nigeria, 29% of the respondents consumed termites, 24% palm weevils, 18% crickets, and 11% grasshoppers (Okore et al., 2014). A survey among student of tertiary institutions in southwestern Nigeria revealed that 58% consumed termites, 36% *Anapleptes trifaciata* (Coleoptera: *Scarabeidae*) and 33% the palm weevil *Rhynchophorus phoenicis* (Coleoptera: *Curculionidae*) (Lawal et al., 2010).

At least 32 Amerindian groups in the Amazon base use terrestrial invertebrates as food (Paoletti et al., 2000a,b). For example, the Guajibo during the rainy season (July/August) derive over 60% of their animal protein from insects, especially grasshoppers and the palm weevil, *Rhynchophorous palmarum* (Coleoptera: *Curculionidae*) (Paoletti et al., 2000a,b). The most important insects eaten by the Tukanoan Indians in the northwest Amazon are palm weevils, ants (*Atta* spp.), termites (*Syntermes* sp.), and noctuid and saturniid caterpillars, providing up to 12% of the crude protein derived from animal foods in men's diets and 26% in women's diets during one season of the year (Dufour, 1987).

TOTEMS AND TABOOS

Indigenous people respect sacred forests, taboos, totems and ancestral spirits, and in this way are their own custodians and legislators of environmental management (Meyer-Rochow, 2009). Offending those is believed to cause illness, death, drought, and disappearance. For example, the Kaingang in the Amazon associate ants with spirits of their ancestors and therefore do not kill ants (Posey, 2002). However, education, Christianity, population growth, colonial policies, infrastructure development, and entrepreneurship are factors that make disappear the fear-of-nature in rural areas and erode sustainable environmental management practices (Dzerefos et al., 2013). For the Kalanga people of the Zaka district in Masvingo, Zimbabwe, edible insects are a source of food and income for the community. A rain-making ceremony is essential to bring vital water for the development of the edible stinkbug, *Encosternum delegorguei* (Hemiptera: *Tessaratomidae*), edible caterpillars, and wild fruits (Risiro et al., 2013). After a harvesting ceremony, the community start to collect the edible insects, and this ensures that insects are harvested only when mature and in abundance. This system protects the system from overharvesting and extinction of the insects. A particular clan is left to oversee the harvesting of the insects, thus avoiding overexploitation.

At certain times of the year the grasshopper *Ruspola differens* (Orthoptera: *Tettigoniidae*), locally called "*nsenene*" is found in large numbers in Uganda and the Baganda consider it a great delicacy. Roscoe (1965, pp. 144–145) mentions that before anyone may eat the first meal of the season, a male member of the grasshopper clan must jump over his wife, or have sexual intercourse with her; otherwise some members of the family would fall ill. The ceremony took place in order that other clans might eat freely of the grasshopper.

A lot of indigenous societies have totem groups. These are groups within tribes, which regard an object, often an animal, as their ancestor (Bodenheimer, 1951; 11, pp. 76–82). Therefore, the eating of the totem animal is forbidden to all members of the totem clan, or only to a very moderate consumption during ceremonies. So, in Australia there are totems for several insect species such as the witchetty grub totem of the Arunta tribe. Once a year a ceremony would take place in order to increase the abundance of the grubs, and only after the ceremony other totem groups are allowed to eat the insect.

The African palm weevil *R. phoenicis* invades palms that have been damaged by other insects such as the African rhinoceros beetle *Oryctes monoceros* (Coleoptera: *Scarabaeidae*) or by human activity such as tapping palm wine. Cut trees also serve as breeding sites. Children in Kwara State of Nigeria are discouraged to eat the larvae (Fasoranti and Ajiboye, 1993). One of the reasons mentioned is that children may get drunk (referring to the palm wine). This may be not just an excuse, as Dounias (2003) mentions that the larvae have a palm wine taste. However, there is also an economic reason (Fasoranti and Ajiboye, 1993): as the larvae are very tasty, it may encourage children to cut the trees depriving the community of palm oil, palm kernels, and palm wine. The same authors mention that members of the Ire clan (the majority are blacksmiths) of the Yoruba tribe in Nigeria do not eat crickets, because they worship the Iron god Ogun, and this god does not accept animals that have no blood.

The larvae of the silkworm *Anaphe infracta* (Lepidoptera: *Thaumetopoeidae*) feed on several trees in central, eastern, and southern Africa. However, the larvae are not so much appreciated as food. It is when the larvae form the communal cocoon and pupate that they are most appreciated. It is even possible to collect the cocoon and store it at home for future use. Both larvae and pupae from the cocoon are eaten. However, in Zambia, with certain ethnic groups it is believed that pregnant women will not be able to deliver the child when they eat the insect. The explanation is that the child is confined to the womb as the larvae to the cocoon (Silow, 1976, p. 122).

Christianity or maybe other more Western beliefs may have an influence of what people can and cannot eat. For example, Ndlovu (2015) mentions "*Insects and animals are used by all Zimbabwean cultures as food and it is from these organisms that the people derive meat foods. Christianity and tradition have prescribed some of these as uneatable and as a result some people may starve amidst some insects or animals that they are prohibited to eat*." Silow (1976, p. 212) mentions from Zambia that because Europeans reacted with disgust when offered caterpillars as food, many villagers came to believe that real Christians do not eat caterpillars. Those that came from mission schools as teachers or public servants often adopted an attitude of aversion toward the larvae, saying that they are food for villagers and laborers.

HARVESTING PRACTICES

The harvesting practices indicate the knowledge the indigenous population has with the biology, behavior, and ecology of the insects. Very often insects are collected by hand. For example, the best part of the day to collect grasshoppers, is early in the morning when it is fairly easy to catch the cold-blooded animals. I will give a number of different practices used for a number of important species.

Using Light or Sound

The most favored termite caste as food is the reproductive one. The swarming termites have their nuptial flight after the first rains following the dry season. After the flight, they shed their wings. The most common way to collect those that emerge during the night is to have a light source above a receptacle of water. They are attracted by the light, fall into the water and are then scooped out. However, it is also possible to make them emerge by pounding rhythmically on the soil with stones and sticks to simulate heavy rainfall and sometimes simultaneously water is poured over the hill (Dounias, 2016).

The edible grasshopper *Ruspolia differens* (Orthoptera: *Tettigonioidea*) is also collected using light sources. Each year there are accidents in Kampala, the capital of Uganda on the road, when women and children, collect those from street lights during the period when they swarm (Owen, 1973, p. 132). However, they are also commercially collected in mass by using huge lamps shining in the sky. They are attracted by the light, hit iron sheets which reflect the light, and fall in drums placed underneath (Agea et al., 2008). The author observed in Lao PDR that a normal light trap (lamp in front of an iron sheet and a bucket with water underneath) was used to collect insects during the night. We were told that the harvest was used for feeding chickens, but that selected ones were reserved for human consumption.

In Cameroon and the Central African Republic, to check whether larvae of the palm weevil *Rhynchophorus* spp. are ready to be harvested, women put their ears to the trunk of the palm tree and decide based on the sound of nibbling larvae (Chesquière, 1947; Muafor et al., 2015). In the Democratic Republic of Congo, sound from whistles made from grass is used by children to attract edible crickets (Malaisse, 1997, p. 240 citing Centner, 1963).

Harvesting From Nesting Structures

Apart from using a light source, the reproductives of termites can be collected directly from the nest (Van Huis, 2003). Holes or trenches are dug near the termite hill; the termites are then attracted by light or fire and then swept into the dug structures. Even tents are built over the holes from where the termites emerge. Depending on the ethnic group, soldiers of termites are sometimes eaten. They are often collected by children, who insert grass stems or reeds into holes of a broken part of the termite hill. The soldiers bite into the stem or reed and are then stripped into a bowl. This is done by Amerindians in the Amazon when collecting soldiers of the termite *Syntermes* spp. (Paoletti et al., 2000a,b). Also in Africa, this is common practice to extract the soldiers (Malaisse, 1997, p. 228).

In Columbia, the future queens of the ant *Atta laevigata* (Hymenoptera: *Formicidae*) have their nuptial flight in April and May. These are collected and considered not only delicacies but are also used as aphrodisiac (Granados et al., 2013). However, the collection from the nest always causes injuries, as the worker and soldier ants defend their nests. Women of the San of the Central Kalahari in the Republic of Botswana locate the nest ant *Camponotus* sp. (Hymenoptera: *Formicidae*) by looking for drained sand (Nonaka, 1996). Once a nest is found, it is poked with a digging stick and the ground around tapped by hand. The emerging ants are collected, but this has to be done quick as the ants bite. Even a few ants are carried home as they are used for seasoning, adding an acidic flavoring to their food.

Queen brood of weaver ants in Lao PDR is produced and harvested from February to April. To collect the brood, use is made of a 4–6 m bamboo stick with sharpened tip and a basket hanging behind the tip. People pierce the nest with the stick and shake it such that the brood falls into the basket (Van Itterbeeck et al., 2014). In the mountainous areas of the central region of Japan, the wasp *Vespula flavipes* (Hymenoptera: *Vespidae*) is a seasonal delicacy (Nonaka, 2010). Collectors attract the wasps by offering them small pieces of meat with tiny ribbons attached to them. When the wasps fly back to the nest, the ribbons enable the collectors to follow the wasp. Once the nest is found, it can be harvested. Often only a part of the nest is harvested in order to allow the colony to recover and ensure future harvests.

Another example in which nests are used to harvest concerns honey pot ants (Hymenoptera: *Formicidae*). Workers of the ants feed nectar to other workers, called repletes, which hang in chambers and have crops swollen with honey. The repletes supply the colony with honey in times of scarcity. They are eaten as a snack by native Americans of the American Southwest (*Myrmecocystus* spp.) and by the aboriginals in Australia (*Camponotus inflatus*) (Conway, 1994). The harvesting in Australia is mainly done by women, who know where the nests are and how the ants get the honey, but seem unaware of how the repletes develop.

From Tanzania (Harris, 1940) and Zambia (Silow, 1976) it is known that the larvae of the silkworm *Anaphe panda* (Lepidoptera: *Thaumetopoeidae*) are eaten. These caterpillars construct communal nests in the branches of trees. In the Kakamega forest in Kenya, sleeve nets are used to decrease mortality by predators and parasitoids (Mbahin et al., 2010).

Exploring Hibernation or Aestivation Sites

In Sudan, the sorghum bug, *Agonescelis versicolor* (Hemiptera: *Pentatomidae*) is not only a pest of sorghum but is also used to extract an edible oil from it (Delmet, 1973). The insect is collected during the dry season when they aggregate in mountain cracks. The edible stinkbug *Encosternum delegorguei* (Hemiptera: *Tessaratomidae*) is eaten by several ethnic groups in South Africa (Dzerefos et al., 2013). The harvest from trees in woodland and plantations is facilitated when the insects aggregate into football-size clusters during the winter season. However, to ward off predators the stinkbugs produce noxious defense chemicals, which stain the skin and affect vision. So, protective gear is worn and harvesting is nocturnal when the insect is immobilized by cold.

Bogong moths *Agrotis infusa* (Lepidoptera: *Noctuidae*) aestivate in rock crevices in the snowy mountains and Victoria Alps in the southeast of Australia after having migrated from up to 1000 km from the inland plains of eastern Australia (Green et al., 2001). The aboriginals, during annual ceremonies, used to smoke them out of the crevices and collect them on bark sheets, nets, or skins (Flood, 1980). The large quantities of moths and the ease of gathering made them a reliable food source. They were carefully cooked, winnowed, and eaten, or preserved by pounding them into cakes (Rigby, 2011). Whereas the consumption of caterpillars is quite common, this is one of the few examples where the adults of Lepidoptera are eaten.

Facilitating Collection

Besides harvesting from nature, the indigenous population also knows ways to encourage the availability of edible insect populations, also called semidomestication. Several examples are given by Van Itterbeeck et al. (2014). For example, providing egg-laying sites of reed and grasses for aquatic Hemiptera in lakes of Mexico, manipulating the habitat to increase edible caterpillars in Africa, and cutting palm trees deliberately to encourage palm weevils to lay their eggs. In the latter case, in the Venezuelan Amazon they make cuts in the trunk of the palm tree to encourage oviposition by palm weevils (*Rhynchophorus* spp.) (Choo et al., 2009). They discern whether the larvae are ready to harvest by counting the days or lunar cycles or examining the color of sawdust expelled from the entry holes larvae create as they tunnel through the palm trunks, and they also know the difference in the development times of the two species, *R. palmarum* and *R. barbirostris*.

A simple kind of rearing to have the edible insect in close proximity to where people live is practised in Africa, where branches with young caterpillars are cut from trees and transported and placed on the same tree species, but near the village (Malaisse, 1997, pp. 207–208).

Exploring Certain Habitats

Harvesting edible insects requires often an intimate knowledge about their biology and ecology. In Australia, the insects that are most commonly eaten by aboriginals are "edible grubs," which are coleopterous or lepidopterous larvae that feed in trunks, branches, or roots of plants. These are locally called bardi or witjuti grubs and there are at least 25 plant species that harbor these insects (Yen, 2005). Australian aboriginals also know about "bush coconuts" or "bloodwood apples" which contain larvae that can be eaten (Yen et al., 2016). The larvae is a scale insect *Cystococcus* sp. (Hemiptera: *Eriococcidae*) which induces galls (outgrowth of plant tissue caused by an insect laying an egg in it) on bloodwoods (*Myrtaceae*) (Semple et al., 2015). Aboriginals eat the larva and the white coconut-like flesh of the inner gall (Gullan and Cranston, 2005).

In the Democratic Republic of Congo, Latham (2005) listed edible caterpillar species to be found on about 50 plant species (Latham, 2005). For African forests in general the biology and ecology of the insect is known for caterpillars, termites, and a number of other insect species (Malaisse, 1997, pp. 199–241). The latter also provides information about harvesting practices and nutritional value of species.

GENDER PARTICIPATION IN COLLECTION AND MARKETING

Women seem to be more involved in the collection and consumption of edible insects than men in Africa (Niassy et al., 2016). Reasons could be: more vulnerability to malnutrition; more dependence on local natural resources; and insects as the only protein and fat sources available.

Tukanoan Indians in the northwest Amazon spend a lot of time in collecting ant and termite soldiers and women do it more than men or children (Dufour, 1987). Men collect insect species that require felling and splitting of trees to harvest the larvae. Men, women, and older children are mostly responsible for collecting caterpillars and palm weevils and the alates of the ant *Atta* sp. and the termite *Syntermes* sp. Concerning the consumption, in the period that insects (in particular ants and termites) are most abundant, they provide 12% of the animal protein in men's diet and 26% in women's diet. Van Huis (2003) also indicates from Africa that insects are often collected by women and children and by the latter when the catch is small or difficult (e.g., cicadas and crickets).

The collection of the edible grasshopper, *R. differens*, a delicacy in Uganda, is an activity for women, who collect the grasshoppers for their husbands, who would in turn buy a traditional dress for the women in Buganda (Agea et al., 2008). Children help their mothers. When collected in large-scale using electricity, lamps, iron sheets, and drums, men tend to dominate. Large-volume trading chains and long-distance trade are lucrative and these are mostly activities of the men.

The collection and processing of the mopane caterpillar, *Imbrasia belina*, (Lepidoptera: *Saturniidae*) in southern Africa is mainly done by poor rural women (Ghazoul, 2006). Women also are the main sellers of mopane caterpillars in market stalls and by the roadside (Kozanayi and Frost, 2002). They sell the caterpillars in small volumes whereas men tend to dominate large-volume trade. In Limpopo, South Africa, female-headed households are more likely to participate in the mopane caterpillar markets, probably because these are resource constrained, lacking access to productive assets (land, labor, capital) which limits their agricultural production capabilities (Baiyegunhi and Oppong, 2016).

On the contrary, in the Central African Republic it is only the men (mainly school boys) who are responsible for the collection of caterpillars, while the sale is only done by women (also school girls), partly (about 25%) by women fruit and vegetable sellers (Mbetid-Bessane, 2005) (Fig. 11.6).

FIGURE 11.6 Caterpillars for sale on the market in the Democratic Republic of Congo. *Photo: Giulio Napolitano, FAO.*

HABITAT DESTRUCTION

Edible caterpillars *Eucheira socialis* (Lepidoptera: *Pieridae*) occur in mountainous regions of Mexico and live on *Arbutus* sp. (*Ericacaeae*) trees, where about 200 of them construct a silken, bag-like nest. However, the trees have been cut to produce firewood, and the nests can hardly be found anymore; the Pjiekakajoo community has only the memory of how, many years ago, the hills were white due to the quantity of nests (Aldasoro Maya and Gómez, 2016).

Since prehistoric times eggs of aquatic Hemiptera of the family *Corixidae* are harvested from bundles of reeds which people keep at the bottom of Mexican lakes. However, drying up of the lakes, improper cultivation techniques, and pollution endangers the harvest (Ramos-Elorduy, 2006).

However, when an edible insect species is in high demand, causing a surge in prices, than overexploitation is a threat. One clear example is the "escamoles" of *Liometopum* sp. (Hymenoptera: *Formicidae*) that are harvested because of their abundance and popularity (Ramos-Elorduy, 2006). They were first collected only by trained men, who retrieved only the reproductive caste in such a way that the nests could be exploited in later seasons. However, now untrained people harvest also the workers, and this leaves the nest in peril. From Australia, Yen (2009b) mentions that even an increased demand by ecotourism and restaurant markets may threaten edible insects such as honey ants and witchuti and bardi grubs.

AGRICULTURAL PESTS AS FOOD

Grasshopper species are often agricultural pests. However, there are several examples in which grasshoppers can be physically controlled by handpicking the insect as food (Fig. 11.7). Rice field grasshoppers of the genus *Oxya* spp. (Orthoptera: *Acrididae*) have been traditional food in most of Asia. In Korea, they were used as side dishes in meals and as a drinking snack. However, insecticide use during the 1960s and 1970s greatly reduced grasshopper populations (Pemberton, 2003). When in the 1980s the government put less emphasis on the countryside, farmers, especially in some highland areas, stopped using insecticides and consequently grasshoppers as food experienced a revival.

In the 1970s, Thailand suffered a major plague of the Bombay locust *Nomadacris succincta* (Orthoptera: *Acrididae*) (Hanboonsong, 2010).

FIGURE 11.7 The red locust, *Nomadacris septemfasciata* (Orthoptera: *Acrididae*), a pest of graminaceous crops, in Malagasy Markets (Betioky and around). *Photo: Annie Monard, FAO.*

FIGURE 11.8 Ready-to-eat fried and seasoned grasshopper in plastic bags, Klong Toey Market, Bangkok, Thailand. *Photo: Arnold van Huis.*

Aerial spraying did not succeed in controlling the pest. From 1978 to 1981 a campaign to urge people to eat the locust was started, as this was an old practice from the past. The publicity campaign promoted the use of locusts for deep-fried snacks, as a ground-up ingredient in crackers, or as a cooking sauce (Fig. 11.8). The campaign was successful. The Bombay locust became a popular food and is no longer considered a major pest by most farmers.

In Assam, India, a root feeding pest, the beetle *Lepidiota mansueta* (Coleoptera: *Scarabaeidae*) has since 2005 become an extremely serious pest of many field crops on Majuli river island in the Brahmaputra River (Bhattacharyya et al., 2015). On this largest mid-river deltaic island of the world, the crop area is 30,000 ha of which 70% is affected. The crops concerned are potato, sugarcane, *Colocasia* sp., and green gram with damages up to 50%. With assistance of the Assam Agricultural University, dishes have been developed such as roasted beetle fry with tomato and plain roasted beetle and beetle curry, which have become popular food (Borah, 2016).

In central Mexico, the grasshopper *Sphenarium purpurascens* (Orthoptera: *Pyrgomophidae*) is a pest of corn, bean, and alfalfa in Mexico. The pest is often controlled by applying organophosphorus insecticides. However, the grasshoppers are also captured and eaten as food. Cerritos and Cano-Santana (2008) showed that manual harvesting reduces the density of the grasshopper and mentioned as advantages: the harvested product can be used as food, no costs of pesticide use, and less environmental contamination. Cerritos Flores et al. (2015) calculated that the estimated biomass of this insect in Mexico would be 350,000 tons per year, generating a gross income of US$ 350 million (10–55 individuals/m^2 over > 1 million ha).

MEDICINAL USES

Insects are not only eaten for food but often used for medicinal purposes. In Meyer-Rochow (2017) examples can be found of using insects against different ailments. For other examples in a number of countries in different continents see Table 11.1.

However, it is sometimes difficult to make a distinction between superstition and real medicinal uses. The "Doctrine of Signatures" may play a role, for example, hairy caterpillars being used to cure baldness (Van Huis, 2002). Meyer-Rochow (1979) mentions that in Kwantung province in China water beetles are used as urine-inhibitor while the dung beetle is used against diarrhea in Thailand. However, one has to be careful to judge quickly if it is superstition. For example, in East Africa it is a widespread custom by adolescent girls to let water beetles of the families *Gyrinidae* and *Dytiscidae* bite in their nipples in order to stimulate breast growth (Van Huis, 2002). One explanation is that girls want to transfer the properties of these breast-shaped beetles to themselves. However, Kutalek and Kassa (2005) showed that gyrinids produce, among other substances, norsesquiterpenes, and that the dytiscids also possess prothoracic defensive glands, which produce, among other substances, hormone-like steroids.

In China it is popular to use caterpillars infected with fungi as medicine (Yen, 2015). The entomophagous fungus *Cordyceps* (Hypocreales: *Clavicipitaceae*) parasitizes larvae, pupae, or adults of insects. Of the 300 species reported so far, no other species is considered as medicinally important and costly as *Cordyceps sinensis* (Arora, 2015). It is a native of high Himalayan mountains in Tibet, Nepal, India, and Bhutan, at an altitude ranging from 3000 to 5000 m, and commonly known as "yartsa-gunbu" in Tibet and as "Keera ghas" or "Keera jhar" (insect herb) in Indian mountains. In nature, it is parasitic on the larvae of a small moth *Hepialus armoricanus* (Lepidoptera: *Hepialidae*). It is world's most efficient and expensive (Liang, 2011) medicinal mushroom and considered as a traditional Chinese medicine having multiple medicinal and pharmacological properties and also used to treat respiratory and immune disorders; pulmonary diseases; renal, liver, and cardiovascular diseases; hyposexuality; and hyperlipidemia with among others as bioactive ingredients: cordycepin, adenosine, and ergosterol (Arora, 2015). It is advertised as combating fatigue (Liang, 2011) and the success of Chinese women athletes,

TABLE 11.1 Articles Dealing With Arthropods as Medicine in Different Continents

Continent	Country and Reference
Africa	Cameroon (Tamesse et al., 2016), Mali (Lehmana et al., 2007), Nigeria (Lawal and Banjo, 2007)
Asia	China (Huang, 1998; Read, 1940; Wang, 2014), India (Chakravorty et al., 2011), Malaysia (Chung et al., 2001), South Korea (Pemberton, 1999; Pemberton, 2005)
Australia	(Cherry, 1991)
Latin America	Brazil (Costa-Neto, 2002; Posey, 2002), Mexico (Ramos-Elorduy de Conconi, 1988)

achieving world records at the 1500 and 3000 m in 1993 was attributed to using this fungus (Steinkraus and Whitfield, 1994).

The weaver ant *Oecophylla smaragdina* is a delicacy of certain ethnic groups living in the forests of Kerala, India. They make oil using hot extraction of crushed worker ants to treat inflammation of joints and skin infections (Vidhu and Evans, 2015).

Chitin is known to have immunological properties, among others in India (Chakravorty et al., 2011). Chitin is the most abundant polysaccharide in the world after cellulose, and it is a material of the exoskeleton of insects, parasites, and fungi. Chitin and chitin derivatives can stimulate innate immune cells and may have beneficial effects on inflammatory responses like those in asthma and other lung disorders (Lee et al., 2008).

An overview of insects used as aphrodisiac in different parts of the world is given by Motte-Florac (2016). Often social insects serve that purpose, for example, gravid new queens of *Atta laevigata* (Hymenoptera: *Formicidae*) in Colombia and Venezuela are given as dowry; in China, powder of the ant *Polyrhachis vicina* (Hymenoptera: *Formicidae*) is a very popular traditional medicine, in particular to "rejuvenate older people"; the weaver ant *Oecophylla longinoda* is used in Cameroon; the queen of termites is often also used as such in Africa (Van Huis, 2002) but also in the Amazon (Posey, 2002).

FROM HARVESTING AND SEMIDOMESTICATION TO FARMING

If we want to promote the eating of insects, it is no option to promote harvesting from nature, as this resource is limited. Edible insects from nature are already endangered by overexploitation, habitat change, and pollution. The other problem with harvesting is that the resource is seasonal and can only be made available throughout the year by preservation practices. It is also not possible to ensure food safety, as edible insects harvested from crops may be contaminated with pesticides, and rearing under controlled conditions obviates such problems. Another way of making insects more available is semidomestication and Van Itterbeeck and Van Huis (2012) give examples for grasshoppers, aquatic Hemiptera, and palm weevils.

Small-scale rearing of crickets appears to be very successful as demonstrated in Thailand where 20,000 farms rear 7500 tons a year (Hanboonsong et al., 2013). It has been shown that small-scale farming of palm weevils is possible: for example, in Thailand (Hanboonsong et al., 2013), Lao PDR (Hanboonsong and Durst, 2014), Cameroon (Muafor et al., 2015), and Venezuela (Cerda et al., 2001).

Rearing has been attempted for the mopane caterpillar but problems due to disease spreading through a captive population remain unresolved; it was technically feasible but was not cost-effective (Ghazoul, 2006).

There are ways of making insects more palatable by rearing them on specific food plants. Such an example is given for caterpillars. When a caterpillar has several host trees, one among which is *Julbernardia paniculata*, they are transferred to this tree and left there for some time to develop and make them tastier as indicated by gourmets (Silow, 1976, p. 210).

This means that industrial rearing of species that can be harvested the whole year, such as crickets, should be attempted and a number of projects aiming to achieve this have been initiated.

CONCLUSIONS

The information available on the practice of eating insects from all over the world is rather limited. What is available are overviews on the practice of insects as food in standard works (Bergier, 1941; Bodenheimer, 1951; DeFoliart, 2012). From some countries, there is a lot of information available due to the activities of some scientists. Examples are Dr. J. Ramos-Elorduy Blásquez from Mexico, who produced an impressive list of publications on the topic (Pino Moreno, 2016), and Latham (2005) and Malaisse and Parent (1980) who both published on edible caterpillar species from the Democratic Republic of Congo. However, a lot of information is also hidden in books dealing with anthropological studies. With the Westernization of tropical societies this information is getting increasingly difficult to get and may get lost. This was already apparent when I studied the traditional use of arthropods in Africa where I mention that my informants often had to consult parents, grandparents, and village elders in order to obtain correct information (Van Huis, 1996). Several authors have indicated that a more concerted effort is necessary to collect this information before it disappears, such as from the aboriginals in Australia (Yen, 2010), the Amerindians in the Amazon (Paoletti et al., 2000a,b), or several ethnic groups in India (Chakravorty et al., 2011). Also, Costa-Neto (2015) mentions from Latin America that many species have not been collected or identified. He also blames the Western bias against the eating of insects: the negative perception of insects as food by Westerners "contaminates" indigenous cultures: people used to eat arthropods, now considering it only for poor and backward people. DeFoliart (1999) and Yen (2009a) feel that acculturation to Western lifestyles tends to cause a reduction in the use of insects as food. Looy et al. (2014) dwell a bit more on the insect cuisine being a threat to the psychological and cultural identity of Westerners.

There is an increasing interest in the West of using insects as food and feed. The 2013 FAO book *Edible Insects: Future Prospects for Feed and Food Security* (Van Huis et al., 2013) was downloaded more than 7 million times. The conference "Insects to feed the world" was attended by 450 participants from 45 countries (Van Huis and Vantomme, 2014). There is an exponential increase in scientific articles on insects as food and feed (Van Huis, 2015). Consulting of the "Web of Science," using the word "edible insects," indicated that only in 2016, 51 articles on edible insects were produced compared to 18 during the 5 years from 2005 to 2009. So instead of looking down at the practice of eating insects as a primitive habit, Westerners now are keen to learn about this food habit from indigenous societies. We now realize that the eating of insects as a protein source has many advantages compared to our conventional production animals. Those advantages can be divided in several categories which have been summarized in Van Huis (2016): nutritonal value being similar or better; less greenhouse gases; less ammonia emissions; less land area needed; low feed conversion efficiency; and insects being able to convert low-value organic side streams into high-value protein products.

Therefore, it is recommended that much more effort will be spent on collecting information about which arthropod species are harvested, preserved, prepared, and marketed. And this should be done before this information is lost. We also see that in some countries like in Thailand there is reappreciation of insects as food and that they are increasingly reared to satisfy the increasing demand (Durst and Hanboonsong, 2015). Also in other tropical countries there is renewed interest. It is necessary to be aware of the Western cultural bias. The challenge is now to collect and evaluate traditional practices.

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