4. Edible insects as a natural resource

4.1 EDIBLE INSECT ECOLOGY

The edible insect resource is primarily a category of non-wood forest products (NWFPs) collected from natural resources (Boulidam, 2010). Edible insects inhabit a large variety of habitats, such as aquatic ecosystems, forests and agricultural fields. On a smaller scale, edible insects may feed on the foliage of vegetation (e.g. caterpillars) or roots (e.g. witchetty grubs), live on the branches and trunks of trees (e.g. cicadas) or thrive in soils (e.g. dung beetles).

Insect ecology can be defined as the interaction of individual insects and insect communities with the surrounding environment. This involves processes such as nutrient cycling, pollination and migration, as well as population dynamics and climate change. Although more than half of all known living organisms are insects, knowledge of insect ecology is limited. Some species that have long been considered valuable for their products – such as honeybees, silkworms and cochineal insects – are well known, while knowledge of many others remains scarce. This chapter points out the need to study edible insect ecology specifically and shows how this knowledge can be applied.

4.2 Collecting from the wild: potential threats and solutions

4.2.1 Threats

Insects provide essential ecosystem services such as pollination, composting, wildfire protection and pest control (Losey and Vaughan, 2006) (see Chapter 2). Edible insects, such as honeybees, dung beetles and weaver ants, eaten extensively in the tropics, perform many of these ecological services. Until recently, edible insects were a seemingly inexhaustible resource (Schabel, 2006). Yet like most natural resources, some edible insect species are in peril. Ramos Elorduy (2006) identified 14 species of edible insect under threat in Hidalgo state, Mexico, alone, including the red agave worm (*Comadia redtembacheri*) (=*Xyleutes redtembacheri*), which is used in mezcal, the Navajo reservation ant (*Liometopum apiculatum*) and the agave weevil (*Scyphophorus acupunctatus*).

A number of anthropogenic factors impose threats on edible insect populations. Collection itself can result in **direct competition** with other predators, undermining population viability (Choo, 2008). Numerous edible insect species are prey or hosts of other insect species (such as coccinellids and parasitic wasps, respectively) and many other organisms, including birds, spiders, mammals, amphibians, reptiles and fish. The effect of reduced insect populations on their predators is unknown. Many edible insect species are predators themselves or decomposers. A reduction in their numbers may have adverse effects on populations of other insect species and affect ecosystem functions. **Overexploitation** is another serious challenge to both the current and future practice of entomophagy (Morris, 2004; Schabel, 2006), particularly if the number of collected individuals (mature and immature) exceeds regeneration capacity (Cerritos, 2009). In addition, the stability and regeneration of edible insect populations is threatened if collection practices become less selective (Latham, 2003; Illgner and Nel, 2000; Ramos Elorduy, 2006). This happens, for example, when mature insects are collected before their first mating or before they lay eggs (Cerritos, 2009). Moreover, many areas are "open-access", and increased collection efforts could threaten existing populations

(Akpalu, Muchapondwa and Zikhali, 2009) (Box 4.1). Matters are further complicated by the fact that indigenous knowledge – which often includes the sustainable use of edible insects and their habitat – is gradually dissipating (Kenis *et al.*, 2006), and inexperienced collectors sometimes resort to **unsustainable collection methods** (Ramos Elorduy, 2006; Choo, 2008).

BOX 4.1

Lao People's Democratic Republic

In the village of Dong Makkhai in the Lao People's Democratic Republic, 21 species of edible insect are collected and sold at the Sahakone Dan Xang fresh food market. On average, 23 percent of the combined household income of the village is derived from the production and sale of edible insects. Most favoured by consumers are ant "eggs" (larvae and pupae of *Oecophylla smaragdina*), grasshoppers (various species), crickets (*Tarbinskiellus portentosus*, *Teleogryllus mitratus* and *Acheta domesticus*), wasps (*Vespa* spp.), cicadas (*Orientopsaltria* spp.) and honeybees (*Apis* spp.). Today, collectors claim they need more time to find similar amounts of edible insects compared with ten years ago, most likely as a result of the increased number of collectors.

Source: Boulidam, 2010.

Finally, like many other natural resources, **damage to habitat**, such as deforestation, forest degradation and pollution (e.g. through insecticides), has placed further stress on edible insect populations (Morris, 2004; Ramos Elorduy, 2006; Schabel, 2006). Host trees are often cut down to increase and facilitate the collection of insects, such as in the case of the edible caterpillar that feeds on the leaves of the sapele tree, with obvious consequences for future harvests (Vantomme, Göhler and N'Deckere-Ziangba, 2004). Often, habitat damage results from other agricultural activities, such as logging and grazing (FAO, 2004). Effects on insects' habitat invariably influence their abundance and distribution (FAO, 2011c). For this reason, the ways in which **climate change** is likely to affect tropical edible insect populations is still relatively unknown. Increasing temperatures could cause certain populations to increase, although periods of extreme heat or drought could also lead to declines (Toms and Thagwana, 2005). The distribution of species may also be affected.

BOX 4.2

Wild harvesting in Asia and the Pacific: past, present and future

In the past, most wild-harvested insects in Asia and the Pacific were consumed exclusively at the village level, and the quantities collected were determined by personal consumption requirements. Today, wild-harvested insects have become an additional source of income. Where possible, more insects are collected so that a portion of the harvest can be sold at markets and the rest is reserved for personal consumption. With fewer insects available for harvest, fewer are consumed at home, and cash incomes are often used to acquire less-healthy foods. Improved access to insect resources (via new roads and modern transport methods) has resulted in more collectors, often coming from afar. Conversely, this has also enabled local villagers to transport their catches to more distant and larger markets.

Continues

Box 4.2 continued

Increased demand has also caused stress on insect populations and their environment. At present, however, there is a dearth of information on the sustainability of the wild-harvesting of edible insects and its ecological implications. In addition to the adoption of sustainable harvesting methods, other forms of producing edible insects have shown potential for reducing pressure on wild edible insect populations, including habitat management, small-scale controlled rearing in confined conditions (e.g. cages and ponds) and industrial production systems (factories). Species suitable for rearing need to be identified. Making use of the high diversity of invertebrates may help to reduce vulnerability to unforeseen shocks such as disease outbreaks and climatic variability.

Source: Yen, 2012.

The problems faced by edible insect populations relate directly to their collection and are deeply rooted in humankind's unsustainable use of the natural environment. It is possible that collecting edible insects will prove to be a threat to the provision of some essential ecosystem services if the practice is commercialized without attention to their sustainable management (boxes 4.2 and 4.3).

BOX 4.3

Mopane and other African caterpillars

Populations of the mopane caterpillar have dwindled since commercialization got into full swing in the 1990s. Mopane populations have encountered the same problem faced by many NWFPs: once a significant market is found, the pressure to overharvest becomes intense, which generally leads to unsustainable use (Sunderland, Ndoye and Harrison-Sanchez, 2011). Poverty, food insecurity and environmental calamity compound the problem.

In the past, restraint was often used in collecting caterpillars (e.g. the first generation of *Cirina forda* was traditionally left untouched "for the birds" and only the second generation was collected; Latham, 2003). Widespread poverty in rural areas coupled with increasing poverty in urban centres, however, has prompted overharvesting. This has turned the promise of a new source of income and cheaper protein into a conservation dilemma. The overharvesting of mopane populations in Zimbabwe, among other countries, has compromised larval production for years (Roberts, 1998; Illgner and Nel, 2000), and even if environmental conditions were to prove optimal, populations are unlikely to recover. Environmental calamities, such as poor yields brought on by drought, will likely trigger a further increase in harvesting this cheap and generally open-access resource. This has already occurred in many parts of the region (Toms and Thagwana, 2005).

Moreover, when caterpillars cannot be reached, desperate livelihood-seekers will often fell entire trees, a practice traditionally frowned on, as the loss of host trees is detrimental to the survival of future populations (Latham, 2003; Morris, 2004; Toms and Thagwana, 2005). Determining sustainable collection levels remains a difficult task, however, and is a key issue for the future development of the sector, largely because several variables are involved in determining population levels. The seasonality of the resource and unpredictability of outbreaks, coupled with a wide range of complex biotic and environmental factors, among others, make this a contentious issue (Stack *et al.*, 2003; Ghazoul, 2006). These issues deserve research and must be addressed if the sector is to develop sustainably and continue to contribute to lives and livelihoods in southern Africa.

Continues

Box 4.3 continued

Many local communities are well aware of the hazardous practices that can harm the mopane woodlands and are equally conscious of the importance of sound protection measures, including adequate fire management, monitoring the caterpillars and their development, the protection of specific habitats, and adherence to restricted harvesting periods (Holden, 1991; Mbata, Chidumayo and Lwatula, 2002; Toms and Thagwana, 2005). The question is whether these local initiatives are realistic in their socio-economic context. The poverty–environment nexus is not new; economic and nutritional incentives commonly drive local communities to overharvest to meet immediate livelihood needs. Conservation policies need to take this into account. For example, harvesting at the beginning of a season would cause the overexploitation of small larvae, which is a wasteful practice. However, efforts to restrict mopane harvesting periods must provide local people with other options for their diets and livelihoods. Moreover, in some areas, local beliefs do not recognize the lifecycle of the mopane, so habitat management (i.e. restricted harvest) is not understood as a necessity (Toms and Thagwana, 2005). Management measures need to balance ecological as well as social, cultural and economic objectives if they are to have any chance at success.

4.3 CONSERVATION AND MANAGEMENT OF EDIBLE INSECT RESOURCES

Among forest managers, there is little knowledge or appreciation of the potential for managing and harvesting insects sustainably. There is also almost no knowledge or experience in manipulating forest vegetation or harvesting practices to increase, maximize or sustain insect populations. Indeed, because many insects cause massive damage and mortality to valuable commercial trees, many forest managers consider virtually all insects as potential destructive pests. What knowledge does exist with respect to managing insects is often held by traditional forest dwellers and forest-dependent people (Durst and Shono, 2010).

Scientists generally speak about biodiversity on three levels: ecosystem, species and genetic. On all three levels it is believed that biodiversity can make significant contributions to food security and improved nutrition (Toledo and Burlingame, 2006). In view of the ecological services insects provide, deemed vital to human life, the conservation of insects and the habitats they occupy has recently received more attention (DeFoliart, 2005; Samways, 2007). The promotion of "flagship species" is used to stimulate public interest in conservation efforts (Simberloff, 1998). In much the same way, conservation biologists identify "umbrella species" as representative species whose protection is believed to indirectly benefit a large number of naturally co-occurring species and their habitats (Roberge and Angelstam, 2004). While these species tend to be large, emblematic mammals, such as giant pandas and tigers, the possibility of edible insect species as flagship species and/or umbrella species protecting other natural resources deserves attention, not least because of the valuable role they have in the provision of essential ecosystem services (Yen, 2009; DeFoliart, 2005). Yet for this to occur, taxonomic knowledge of insects – which still lags far behind that of vertebrates and plants – needs to improve (Winfree, 2010). There is also relatively little documented knowledge of insect species (compared with vertebrate animal and plant species) about contemporary threats and conservation and management requirements (Yen, 2012). Although insects account for the largest proportion of biodiversity in all forest ecosystems, they continue to be the least studied of forest organisms (Johnson, 2010).

Samways (2007) offered a rare yet promising contribution to insect conservation efforts by describing in detail how insect populations and habitats can be managed and monitored effectively and by identifying the following six principles for maintaining adequate insect population levels: maintain reserves; maintain as much quality landscape heterogeneity as possible; reduce contrast between remnant patches and neighbouring disturbed patches; set aside land for insects outside reserves; simulate natural conditions and disturbance; and connect similar patches of quality habitat. Boulidam (2010) added that efforts in edible insect management ought to focus on edible insect species with the greatest potential and value. These principles are particularly important for forestry, ecology and entomology experts. However, insect conservation efforts will remain futile without adequate support from national and international research and development organizations and local communities (Schabel, 2006; Cerritos, 2009; Boulidam, 2010).

Current gaps in insect ecology are a major impediment to the development and sustainability of entomophagy. Issues that require urgent research include identifying edible insect species, estimating populations, and understanding the ecology and biology of species and their habitats and the factors that determine their abundance. Increased knowledge on factors such as peak abundance, population dynamics and life cycles is essential to counter the depletion of edible insect resources (Ghazoul, 2006; Cerritos, 2009). Tapping into indigenous knowledge is likely to prove particularly useful. In light of the above, obvious next steps in the field of research on edible insects are to sustainably increase the production of wild and reared edible insects, through either expansion or intensification, and to implement ecologically sound forest management practices to this end (Johnson, 2010).

Foresters and forest industries have long considered caterpillars as pests because they feed on fresh leaves (tree foliage) and are therefore perceived to be harmful to tree populations. In reality, however, trees respond to such browsing by producing more foliage. N'Gasse *et al.* (2004) observed that leaf consumption by caterpillars had only a limited impact on trees. In fact, the collection of caterpillars in the forest could be considered a method of biocontrol, so long as trees are not cut during the caterpillar harvest (Vantomme, Göhler and N'Deckere-Ziangba, 2004) (see section 4.3 for more on pest management). In exchange, caterpillar protection could greatly benefit from host tree conservation and management (Holden, 1991; Munthali and Mughogho, 1992; Chidumayo and Mbata, 2002; Toms and Thagwana, 2005).

A red list of endangered insects in East Africa. The International Institute for Tropical Agriculture has established a red list of 34 endangered insect species in Benin. The principal threats to insects involve the deterioration or, in some areas, the disappearance of habitats due to pollution, the overextension of agriculture, poor agricultural practices, uncontrolled burning, the uncontrolled cutting of timber, the disrespect of protected areas and, in the long term, climate change and the disappearance of pollinators. Given that most threatened insects live in forest ecosystems, deforestation is one of the primary concerns (Neuenschwander, Sinsin and Goergen, 2011). The list includes one species that is certainly eaten in Central Africa: the African Goliath beetle (*Goliathus goliathus*) (Bergier, 1941). In Benin, this species is threatened by a reduction in the availability of its preferred host tree, the rare *Holoptelea grandis* (Ulmaceae). Because the Goliath beetle can now be easily reared, hunting for insects has diminished and is no longer considered a threat to these trees (Neuenschwander, Sinsin and Goergen, 2011).

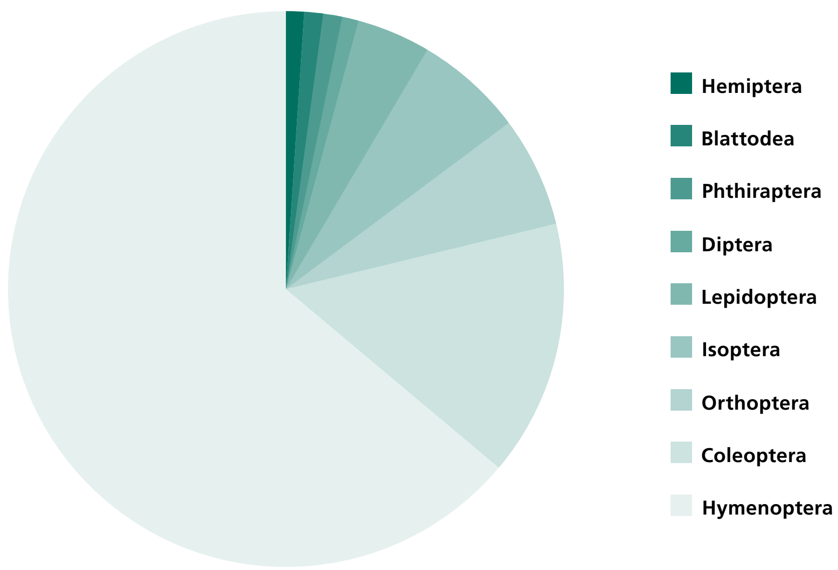
Biodiversity of micro-organisms and invertebrates for food and agriculture. FAO's Commission on Genetic Resources for Food and Agriculture (CGRFA) and the Treaty on Plant Genetic Resources for Food and Agriculture recognize the fundamental role that micro-organisms and invertebrates play in food security and sustainable agriculture through the services they provide in food production ecosystems and the natural environment. Among the functional groups distinguished by the CGRFA are: pollinators; biological control agents (biocontrol); soil ecosystem engineers and regulators; food providers and providers of non-timber forest goods (e.g. silk, honey, edible insects); and aquatic invertebrates and their contribution to fisheries and aquaculture (which could be extended to include the use of invertebrates as feed for conventional livestock) (FAO, 2009a). FAO has a long tradition of technical work on the importance

BOX 4.4
Insects and biodiversity in Brazil

Brazil is recognized globally for its status as a biodiversity hotspot (Myers *et al.*, 2000). The country also hosts a rich cultural diversity, with a remarkable 222 indigenous ethnic groups as well as several other groups, including artisanal fishermen, Amazon caboclos (or river-dwellers) and Afro-Brazilians, also known as quilombolas. This combined diversity is known as biosociodiversity (Costa Neto, 2012).

A total of 135 edible insect species belonging to nine orders (Figure 4.1) and 23 families in 14 of Brazil's 26 states have been documented in literature. Of these, 95 have been identified to the species level and 18 to the genus level, while others are known only by their native names. The most consumed species are in the Hymenoptera (63 percent), Coleoptera (16 percent) and Orthoptera (7 percent) orders (Costa Neto, 2012). Given Brazil's vast biosociodiversity, "it could be stated that anthropoentomophagy is underestimated, since nutritious edible insects are abundantly available" (Costa Neto, 2012).

FIGURE 4.1
Distribution of insects, by order, Brazil



Source: Costa Neto, 2012.

of micro-organisms and invertebrates for food and agriculture. Among these are the Organization's programmes and strategies on integrated pest management (IPM). Through the CGRFA, focus on this "hidden biodiversity" has increased.

FAO also coordinates two global initiatives of the Convention on Biological Diversity, which have been established in recognition of the essential services provided by micro-organisms and invertebrates across all production systems: the International Initiative for the Conservation and Sustainable Use of Pollinators, and the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity. For an example of national insect biodiversity, see Box 4.4. Many partner organizations collaborate with FAO on these important initiatives.

4.4 SEMI-CULTIVATION OF EDIBLE INSECTS

Better knowledge of a particular insect species' biology and ecology can lead to more than an understanding of its seasonality, for example, or the development of efficient tools to collect them. It may also enable the manipulation of an edible insect's habitat at a small or large scale, such as the insects' behaviour and availability throughout the year (Van Itterbeeck and van Huis, 2012). This is termed **semi-cultivation**, as it resembles cultivating – a process that promotes the growth (or quality) of an organism through the use of labour and skill. Semi-cultivation rarely involves the tending of insects (as opposed to actual cultivation, or farming, which is the topic of Chapter 7). Semi-cultivated insects are available in the wild and are generally not grown in captivity (although some may be captive during part of their development, such as the palm weevil larvae, which is farmed as larvae in plastic containers in Venezuela; Cerda *et al.*, 2001). Semi-cultivated insects are thus not isolated from their wild populations. Palm weevil larvae in the Amazon Basin, Indonesia, Malaysia, Papua New Guinea, Thailand and tropical Africa, caterpillars in sub-Saharan Africa, bamboo caterpillars in Thailand, eggs of aquatic Hemiptera in Mexico and termites in sub-Saharan Africa are all examples of semi-cultivated insects, the habitats of which are manipulated to a greater or lesser degree. Evidence of landscape manipulations for food can be found in archaeological records, suggesting that they were key stepping stones in the development of sedentary food production and domestication (Barker, 2009). The manipulations intended for producing edible insects are therefore useful as first steps towards a more controlled production. Semi-cultivation has many benefits, not least of which is ensuring the availability and predictability of edible insects. The activities surrounding semi-cultivation have the potential to contribute to both edible insect habitat conservation and food security. In the tropics, emphasis should be placed on maximizing the productivity of semi-cultivation practices already in place. Such activities could be developed for other edible insect species, provided there is sufficient understanding of their biology and ecology.

4.4.1 Palm weevil larvae

Classic examples of semi-cultivation involve the larvae (grubs) of *Rhynchophorus palmarum* (Central and South America), *R. phoenicis* (Africa) and *R. ferrugineus* (Southeast Asia) (see also section 2.3.2). The most detailed information is available on *R. palmarum*. Palm trees can be considered as *controlled* variables because they are felled deliberately and at a chosen location and time. The process is relatively simple: people return to the trunks one to three months after felling to harvest the larvae (Choo, Zent and Simpson, 2009). Some Amerindians employ this technique as a strategy in long hunting and fishing trips that keep them away from their villages for extended periods (Dufour, 1987).

Amerindians in the Bolivarian Republic of Venezuela are known to use their indigenous knowledge of palm weevils to control the relative quantity of the larvae of two palm weevil species, the South American palm weevil *R. palmarum* and the Bearded weevil *Rhinostomus barbirostris*, the females of which oviposit (lay eggs) in the same trunks. These two weevil species differ in their ovipositing biology: *Rhynchophorus palmarum* adults feed, mate and oviposit on exposed inner palm tissue of felled or naturally fallen palms, whereas *R. barbirostris* oviposit on the intact surface of the trunk and can thus use the entire trunk length to lay eggs. *R. palmarum* adults arrive at the trunks earlier than *R. barbirostris*. Thus, when the former are preferred, softer inner tissue is made available by producing deep cuts in the trunk, making larvae of *R. palmarum* more abundant than those of *R. barbirostris*.

A similar technique is employed with the sago palm (*Metroxylon sagu*) in Papua New Guinea (Mercer, 1994). The mating behaviour of the palm weevil (*R. ferrugineus papuanus*) is gregarious, which easily results in 100 grubs or more in a single trunk. As adult weevils only oviposit in unworked portions of trees that are cut to harvest starch, deliberately felling trees for harvesting larvae increases their numbers. In Papua New Guinea, palm trees that render small quantities of starch are often reserved for the semi-cultivation of palm larvae (Townsend, 1973).

Cerda *et al.* (2001) documented simple cottage methods used by Amerindians in Venezuela to rear the South American palm weevil *R. palmarum* on other crops. The weevil is encouraged to grow on the moriche palm (*Mauritia flexuosa*) because weevils grown on this palm have a protein content of 40 percent on a dry weight basis, which is much higher than those reared on other palm species. Amerindian tribes collect the larvae from the trees after four weeks and continue to rear them for several weeks in plastic containers near home. They feed the larvae with banana pseudostem, vegetable refuse and fruits (Cerda *et al.*, 2001). A pineapple–sugarcane diet has also been explored (Giblin-Davis et al., 1989). Overexploitation was considered to be a potential problem because palm trees are cut in order to trigger egg-laying by the adult beetle and subsequent larval growth. Although Cerda *et al.* (2001) reported that 31 plant species belonging to 12 families can host palm weevils for feeding, careful management of palm trees is still vital to ensure the sustainability of the practice.

Traditional peoples manage and protect some plant species, including palm trees (Politis, 1996), and intervene in the landscape through, for example, forest clearance, planting and plant tending (Barker, 2009). In many parts of the world, trees are felled deliberately to stimulate the production of palm weevil larvae, suggesting that these larvae are a prime insect food source. When trees have been felled to harvest starch, collect fruit, and/or tap the tree for its sap to make wine, the larvae grow in unworked portions of the trunk and have been referred to as byproducts (Dufour, 1987) and second crops (Bodenheimer, 1951). Although dual production may very well be intended, great care should be taken when referring to palm weevil larvae as true byproducts (Van Itterbeeck and van Huis, 2012).

4.4.2 Caterpillars

Box 4.5 presents two examples of habitat management that can increase caterpillar abundance: chitemene shifting cultivation and fire management. As such, these activities can be considered semi-cultivation. Similarly, host tree planting and refraining from cutting down host trees increases egg-laying sites for caterpillars (Takeda, 1990; Latham, 1999). Latham (2003) provided an extensive list of edible caterpillar species and their host plants, and also showed how traditional regulations concerning caterpillar collecting were being maintained or re-instated. Mbata and Chidumayo (2003) described in detail systems in the Kopa area in Zambia in which all levels of the local society are involved: high-density moth egg sites are detected, and the appearance of the first instar and the final instar (the only instar allowed to be collected among the locals) are monitored. Based on these observations, the timing of collection is regulated, and, when necessary, temporal restrictions are imposed on collecting caterpillars. Rituals are also performed and ceremonies held, thus strongly fixing the caterpillars in local culture. In Bas-Congo in the Democratic Republic of the Congo, locals reintroduce caterpillars such as *Cirina forda* on Acacia trees near their houses and allow the caterpillars to grow until they are ready to eat. Some of the caterpillars can be left to pupate. These will develop into adult butterflies, which will lay their eggs in the same area. In this way a caterpillar supply is ensured for the following season (Latham, 2003).

Given the problems facing wild populations – such as irregular and unpredictable outbreaks (Hope *et al.*, 2009) – the domestication of caterpillars and host plants in agroforestry systems is being explored. For example, larvae can be protected from drought, heat and predation – which contribute to mortality in the wild – by using simple techniques such as protective shade cloth sleeves covering branches and shade houses. The long-term viability of such enterprises, however, is unclear. Captive breeding is vulnerable to viral and bacterial diseases and to parasitoids, a problem that also occurs in wild populations of mopane. Recent research suggests that mopane farming should be kept small-scale to reduce the impact of viral diseases. It is better, therefore, for a village to have multiple small-scale farms than one large farm, so that failing farms can easily be restocked with healthy eggs or larvae if information and resources are exchanged readily between farms. Such arrangements cannot be developed overnight, however, as it implies an established degree of trust between farmers. Disease management and control in mopane caterpillar farming deserves serious attention if semi-domestication is to be a serious proposition. The development of captive breeding does not exclude the continued development and success of managing wild populations. On the contrary, further research into reducing mopane mortality from disease would equally benefit wild populations and contribute to the development of a caterpillar-rearing sector (Ghazoul, 2006).

Considering the economic and nutritional importance of mopane caterpillars in Africa, more scientific knowledge relating to wild mopane caterpillar ecology and population biology is necessary. The same is true for a host of other edible caterpillars (Munyuli Bin Mushambanyi, 2000). This is arguably a result of minimal interest in the issues arising from a bias in Western science against insects as a viable source of food and income (Kenis *et al.*, 2006). Filling existing research gaps will provide the knowledge needed for the sustainable management of wild mopane caterpillar populations. Greater accuracy in determining outbreaks, for example, and a better understanding of the affects of diseases and parasitoids on mopane caterpillar populations, would benefit this farming and, in turn, local communities (Ghazoul, 2006).

In Thailand, the Forest Products Research Division of the Royal Forest Department conducted research into the bamboo caterpillar, *Omphisa fuscidentalis*, also known as bamboo worm. The caterpillars reside in bamboo internodes, where they feed on the soft inner tissue. Although the bamboo must be cut and opened to harvest the caterpillars, this does not kill the culm. The bamboo that is inhabited by caterpillars can be identified by the hole made by the young larvae when they enter, as well as by internode size, although amateur gatherers have been known to fell bamboo needlessly in search for caterpillars. Nevertheless, felled bamboo can be used as fuel and garden materials and in the manufacture of handicrafts. The research, including data on the bamboo worm's biology and ecology, was published by the Thai Royal Forest Department in a manual in 2000. Among other things, this manual encourages locals to plant bamboo to compensate for the damage caused by harvesting bamboo caterpillars. Methods are provided for semi-cultivating the bamboo caterpillar: for example, mature larvae can be introduced to bamboo shoots placed in water and covered in a net sleeve at home. The resulting adults then mate, and adult females deposit eggs on the bamboo. Current research is looking into shortening the diapause to allow for year-round production (Singtripop, Wanichacheewa and Sakurai, 2000).

BOX 4.5

Effect of fire management and shifting cultivation on caterpillar populations

Fire management

Fire is often used as a management tool in forestry. In Kasungu National Park, Malawi, where the practice is commonplace, fire policies have reportedly been affecting caterpillar yields (Munthali and Mughogho, 1992). Late burning (from September to October) is particularly hazardous for caterpillar populations as it coincides with the egg-laying period of adult moths. In contrast, early burning (June to July) increases caterpillar yield, probably because it decreases the abundance of predators of moth eggs and larvae and promotes the growth of the young leaves on which caterpillars feed.
It was initially believed that the highest caterpillar yields could be found at tree heights of 1–3 m – coincidentally also within the reach of harvesters. If this is true, a rotation

Continues

Box 4.3 continued

burning scheme promoting growth of stems between 0 m and 4 m might point the way to a sustainable forest management policy in the woodlands, which would benefit lives and livelihoods at the same time (Munthali and Mughogho, 1992). However, a later study suggested that the majority of mopane caterpillars (70 percent) are found above 3 m in host trees (Roberts, 1998). This difference might be explained by differing local conditions in these habitats. Thus, fire management policies should be determined at the local level, and above all they should take into account the important forest resources – such as the mopane caterpillar – that people depend on for food security and livelihoods.

Chitemene shifting cultivation

Chitemene shifting cultivation (i.e. clearing the forest canopy) in fallow lands stimulates the re-growth of caterpillar host trees and thereby increases the potential abundance of caterpillars (Chidumayo and Mbata, 2002). To some extent, selective cutting may favour caterpillars, as it does not appear to negatively affect woodlands. Forest reserves could provide an ideal setting for such forms of habitat management, also providing a forum for educating local communities on the importance of habitat conservation. The role of forest reserves could be reconceptualized to include areas designated for caterpillar production, which would also serve to counteract logging activities on caterpillar host trees (N'Gasse, 2004). However, the long-term effects of such management strategies, as well as the effect on the proportion of tall trees to shorter ones, require further research (Chidumayo and Mbata, 2002).

4.4.3 Eggs of aquatic Hemiptera

The Aztecs considered the eggs of aquatic true bugs as delicacies and referred to them as ahuauhtle; to the Spanish conquistadores they were known as Mexican caviar (although the term is also used for ant larvae) (Bachstez and Aragon, 1945). The ahuauhtle (the adults of which are called axayacatl) measure about 0.5–1 mm. Among the most popular are the eggs of *Corisella*, *Corixa* and *Notonecta* species (Bergier, 1941; Bachstez and Aragon, 1945; Parsons, 2010).

Encouraging the production of ahuauhtle is relatively simply. Female bugs deposit their eggs on aquatic vegetation in lakes (Bergier, 1941; Bachstez and Aragon, 1945; Parsons, 2010). The eggs are semi-cultivated, therefore, by providing egg-laying sites for the female bugs. Bundles of twigs, grasses or reeds (e.g. *Carex* sedges; Guerin-Meneville, 1857) are bound together with a rope and spaced out on the bottom of the lakes (still and shallow water works best), using stones to keep them in place (Guerin-Meneville, 1857; Ramos Elorduy, 1993; Parsons, 2010). Long U-shaped grass/reed bundles, placed at 1 m intervals, have been used more recently. The female Hemiptera lay their eggs on these bundles and can be harvested easily by removing the bundles and shaking them. However, harvests have declined in many of these lakes in recent decades due to pollution (Ramos Elorduy and Pino, 1989).

4.4.4 Termites

Farina, Demey and Hardouin (1991) describe a simple method for semi-cultivating termites involving the replication of interior mound conditions by providing a mix of humidified cellulose (e.g. paper, cardboard and dried plant material) and soil in a cool, dark place. In Togo, local products are used exclusively for the semi-cultivation of termites – an old canari (a plastered water-storage recipient), dry sorghum stems or other cereals, water, a piece of an old jute bag, a stone and some moist soil. A simple wooden construction is made to hold the canari in place over a mound entrance hole; termites can be harvested in 3–4 weeks. Termite mounds that are under construction are ideal, but old mounds also fare well (Farina, Demey and Hardouin, 1991).

4.5. PEST MANAGEMENT

Many edible insects are considered pests and threats to agricultural crops (Box 4.6), and treatment with chemical control methods such as pesticides and insecticides is commonplace in many parts of the world. Manual collection of these pests could not only feed mouths and save crops but also benefit the environment by reducing and mitigating the need for pesticides.

BOX 4.6

The case of the cockchafer bug: from agricultural pest to delicacy to conservation controversy

Though hard to believe, the may bug, and in particular the common European cockchafer bug (*Melolontha melolontha*), has featured as a food item in Europe as far back as the eighteeenth century. Erasmus Darwin (1731–1802), a natural philosopher, physiologist, inventor, poet and grandfather of Charles Darwin, wrote about the may bug as food in *Phytologia* in 1800:

> I have observed the house sparrow destroy the Maychafer, eating out the central part of it, and am told that turkeys and rooks do the same; which I thence conclude might be grateful food, if properly cooked, as the locusts or termites of the East. And probably the large grub, or larva of it, which the rooks pick up in following the plough, is as delicious as the grub called Grugru, and a large caterpillar which feeds on the palm, both of which are roasted and eaten in the West Indies. [The latter probably refers to *Rynchophorus* species, the palm weevil, eaten as a delicacy in virtually all tropical countries.]

Years later (on 13 February 1878) the may bug sparked controversy. In an effort to counter a law calling for the destruction of agricultural pests (in particular the may bug), French senator Tesselin published a recipe for the cockchafer in the *Journal Officiel*:

> Catch the may bugs, pound them and put them through a sieve. For making a thin soup, pour water over them. For making a fat soup, pour bouillon over them. This gives a delightful dish, esteemed by the gourmets.

Remarkably, the may bug became the main ingredient of a traditional soup made in a handful of European countries called cockchafer soup. Until the mid-twentieth century, in fact, this soup – which is comparable with lobster soup – was considered a delicacy in France, Germany and several other European countries. Despite the dish's status as a delicacy, controversy has continued through the years. Today, efforts are being waged to protect the species and its habitat. The case of the cockchafer can be viewed as an encouraging example of the development of edible insects as sources of food because it shows that perceptions can and do change.

Source: Wikipedia, http://de.wikipedia.org/wiki/Maik%C3%A4fersuppe

Cerritos and Cano-Santana (2008) documented the effectiveness of handpicking the popular edible grasshoppers called chapulines (*Sphenarium purpurascens*) from fields of alfalfa to protect the crop and the insect without chemical control (see also section 2.2 on grasshoppers). With comparable (although slightly lower) crop yields, mechanical control has the advantage of considerably lower environmental damage as well as generating an extra source of nutrition and income from the consumption and sale of grasshoppers. Pesticide use is frowned on in many Arab regions; handpicking locusts reduces the impact of the insect on crops and provides an additional source of food. Saeed, Dagga and Sarraf (1993) demonstrated the occurrence of pesticides toxic to humans in locusts that were captured during an outbreak, thereby indicating a health risk to humans consuming these locusts. Cerritos (2009) identified 15 edible insect species considered pests of global or local importance in agro-ecosystems that could be controlled through strategies of alternative management, such as mechanical harvesting, and used widely for human consumption (Table 4.1).

TABLE 4.1
Edible species considered as pests of global or local importance in agro-ecosystems, which could be controlled through strategies of alternative management and used widely for human consumption

Order	Species and common name	Distribution
Orthoptera	*Locusta migratoria*, migratory locust	Intercontinental
	Locustana pardalina, South African migratory locust	Africa
	Schistocerca gregaria, desert locust	Intercontinental
	Zonocerus variegatus, variegated grasshopper	Africa
	Sphenarium purpurascens, chapulines	Mexico
Coleoptera	*Rhynchophorus phoenicis*, African palm weevil	Africa
	Rhynchophorus ferrugineus, Indian red date palm weevil	Asia
	Rhynchophorus palmarum, American palm weevil	America
	Augosoma centaurus, scarab beetle	Africa
	Apriona germari, mulberry longhorn stem beetle	Asia
	Oryctes rhinoceros, coconut rhinoceros beetle	Intercontinental
Lepidoptera	*Agrius convolvuli*, sweet potato hawkmoth	Zimbabwe, South Africa
	Anaphe panda, wild silkmoth	Africa
	Gynanisa maja, emperor moth	Africa

Source: Cerritos, 2009.

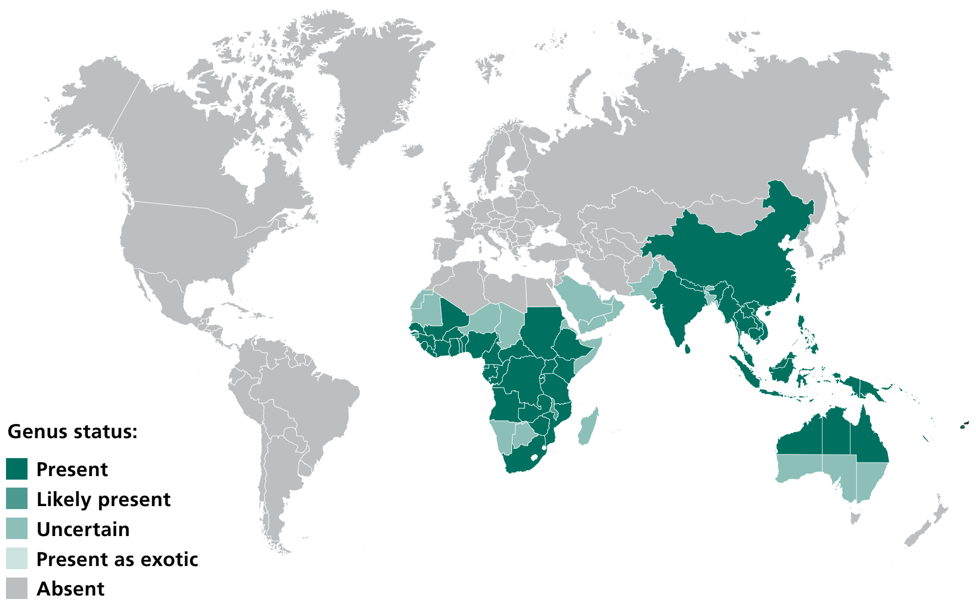
A different system of ecologically sound pest management involves weaver ants of the genus *Oecophylla*. This generalist and aggressive predator is a highly efficient biocontrol agent for a variety of commercially important tree species (Peng, Christian and Gibb, 2004). Offenberg and Wiwatwitaya (2009b) showed that there is strong potential to use the weaver ant *Oecophylla smaragdina* both as a food – given the popularity of the brood in countries like Thailand and the Lao People's Democratic Republic (Yhoung-Aree and Viwatpanich, 2005; Sribandit *et al.*, 2008) – and as a biocontrol agent in mango plantations.

4.5.1 Case study: *Oecophylla* spp. weaver ants

The Asian weaver ant, *Oecophylla smaragdina*, is consumed in China, India, Indonesia, the Lao People's Democratic Republic, Myanmar, Papua New Guinea, the Philippines and Thailand (DeFoliart, 2002; Yhoung-Aree and Viwatpanich, 2005; Sribandit *et al.*, 2008). Its African sister species, *O. longinoda*, is consumed in the Democratic Republic of the Congo (DeFoliart, 2002), and in Cameroon a sauce is made based on the worker ants (A. Dejean, personal communication, 2012). The range of the Asian weaver ant, *O. smaragdina*, extends from India to Australia, while the green tree ant, *O. longinoda*, is endemic to tropical Africa. Weaver ants are so-called because they bind ("weave") the leaves of living trees together with silk, secreted by their larvae, to form nests. One ant colony consists of numerous nests, often occupying several trees (Lokkers, 1990).

Typically it is the larvae and pupae ("ant eggs"), particularly the large ones destined to become virgin queens, that are consumed. Adults (workers, virgin queens and males) are less favoured but are used as condiments. Worker ants are added to fish soups in the Lao People's Democratic Republic because of their sour taste, much like lemon is used in many Western countries (J. Van Itterbeeck, personal communication, 2012). Weaver ants also serve as traditional medicine in China and India (Chen and Akre, 1994; Oudhia, 2002) and by Australian Aborigines in northern Australia (Yen, 2005). In Indonesia, the larvae and pupae are used as feed for songbirds and as fishing bait (Césard, 2004a). The Asian weaver ant has been used in mango orchards in Australia's Northern Territory as a biocontrol agent of the mango leafhopper, *Idioscopus nitidulus* (Peng and Christian, 2005) (see Figure 4.2).

FIGURE 4.2
Geographic distribution of *Oecophylla* species



Source: Guénard *et al.*, 2010.

Weaver ants are highly territorial (Hölldobler, 1983) and capture many species of insect that feed on their host trees, which include cashew, cacao, coconut, mango, tea and *Eucalyptus* trees (Peng *et al.*, 2004). As far back as 304 CE they were used in China to protect citrus trees from insect pests. The quality and yield of fruits treated with such biocontrol methods have proved greater than those obtained through conventional insecticide application (Van Mele, 2008). Weaver ants are a perfect example of successful pest management.

Livelihoods

In Thailand and the Lao People's Democratic Republic, the collecting season peaks in February to April and is largely determined by the availability of larvae and pupae destined to become virgin queens (Sribandit *et al.*, 2008; J. Van Itterbeeck, personal communication, 2012). The areas in which ant nests are found are considered open access (Césard, 2004b; J. Offenberg, personal communication, 2010; J. Van Itterbeeck, personal communication, 2012). Larvae and pupae collection, usually carried out by women, provides cash income for many rural people. It is also a valuable source of nutrition: fresh larvae and pupae provide 7 g of protein and 79.2 kilocalories of energy per 100 g (Yhoung-Aree, Puwastien and Attig, 1997). Sribandit *et al.* (2008) estimated that the average household in Thailand consumes 49 kg of larvae and pupae per ant-harvesting season, with the ant harvest constituting some 30 percent of yearly income (and occupying less than 20 percent of labour engagements). This endeavour is therefore an important part of many families' livelihood strategies. Césard (2004b) reported, however, that there are constraints on commercialization due to limited preservation techniques and associated declines in price.

Collection practices
Queen larvae and pupae (ant eggs) are popular foods in Thai urban and rural areas (Yhoung-aree, 2010) and are collected intensively in the latter (Sribandit *et al.*, 2008). Collection is done by penetrating the nest with a long bamboo stick with a basket, bag or net attached to one end to catch the "eggs" inside the nest (Césard, 2004b; Sribandit *et al.*, 2008; J. Van Itterbeeck, personal communication, 2012). "Eggs" do not appear to be overharvested, most probably because population regeneration is quick, for a number of reasons: collectors intentionally refrain from harvesting all larvae and pupae from one nest; the nests of founding queens are usually not collected (e.g. in the Lao People's Democratic Republic, such nests are usually very small and therefore they are ignored because a small yield of ant eggs is anticipated); traditional practice involves rotating between different forest patches over the course of the season; and only a very small fraction of the worker ants are removed (Césard, 2004b; Sribandit *et al.*, 2008; Van Itterbeeck, personal communication, 2012). Nevertheless, care must be taken because, as with most NWFPs, when economic incentives increase (which has already happened in some areas) so too do the number of collectors and, in turn, so does harvesting pressure. Thai collectors have already reported a decline in availability, although it is unsure if this is due to collecting practices, harvesting pressure or forest loss. Moreover, strong competition between collectors risks endangering the continuation of traditional rotation systems and could lead to the adoption of more destructive tools and methods (Sribandit *et al.*, 2008). More positively, it has been observed that when other subsistence activities are present to complement (daily) income, fewer ant eggs tend to be collected (J. Van Itterbeeck, personal communication, 2012).

Weaver ants (*Oecophylla* spp.) can be successful in controlling insect pests, but the aggressive workers are often considered a nuisance, especially when harvesting produce such as fruits. Recent research in Thailand suggests that the use of weaver ants as a biocontrol can be maintained while harvesting the queen larvae and pupae, which are not vital for colony survival. The number of larvae and pupae of the worker caste produced in a colony during the peak ant egg collecting season is believed to be small (Offenberg and Wiwatwitaya, 2009a); these are often not collected in Thailand. Harvested nests even develop higher worker ant densities in time and thus the biocontrol capacity is maintained, if not increased. A new agricultural system could be established in which high fruit yields and quality are achieved and pest insects – that is, weaver ant queen larvae and pupae – are converted into easily manageable and accessible protein foods (Offenberg and Wiwatwitaya, 2009b). In a study in Thailand, Offenberg (2011) identified Asian weaver ants as a very promising insect to farm commercially.