

Insect biodiversity in the food system²

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Abstract

Humans collect and eat over 2000 insect species, from all major orders. Besides this wild harvest, insect farming is rapidly becoming common across the world, from small farms to industrial rearing facilities. This protein for livestock and people could conserve biodiversity by replacing soy farmed on deforested land and fishmeal caught from oceans. However, there are safety concerns, *eg*, related to the diets fed to captive insects. Overharvesting of wild insects could put some species at risk. Better conservation measures are required, especially since an estimated 40 percent of the world's insects may become extinct in the next few decades, largely related to habitat destruction and climate change. Empirical evidence of insect ecology and local knowledge is needed to inform sound harvesting and conservation practices, as well as appropriate regulation of wild harvesting. Case studies from various countries highlight different practices, from formal protected areas to strategic approaches.

Diversity of edible insects

Of an estimated 8.5 million species of terrestrial invertebrates in the world, many are still undescribed, and only a few are eaten by humans (Figure 1). Many invertebrate species, especially insects, have become extinct or threatened in recent years (Antonelli *et al*, 2023; Collen *et al*, 2012). Among terrestrial invertebrates, most edible species are insects, and out of 1.5 million described insect species (Antonelli *et al*, 2023), just over 2100 are known to have been eaten (Table 1) (Jongema, 2017). Even fewer species of terrestrial invertebrates (about 100) are eaten in substantial quantities. The value of global trade in edible insects was estimated

to reach USD 1.2 billion in 2023 (Liceaga, 2021). Edible insects and snails tend to be the larger, more gregarious species (Dufour & Sander, 2000).

Table 1. Edible insects and spiders

Order	Common names	Recorded edible species
Araneae (of the class Arachnida, not insects)	Spiders	15
Blattodea	Termites	59
Blattodea	Cockroaches	37
Coleoptera	Beetles, grubs	659
Dermaptera	Earwig	1
Diptera	Flies	37
Ephemeroptera	Mayflies	10
Hemiptera	True bugs, cicadas	237
Hymenoptera	Ants, bees, wasps	321
Lepidoptera	Caterpillars, moths, butterflies	362
Megaloptera	Dobsonflies	4
Odonata	Dragonflies	61
Orthoptera	Grasshoppers, locusts	278
Phasmatodea	Stick insects	7
Phthiraptera	Lice	3
Plecoptera	Stoneflies, salmonflies	9
Psocoptera	Barklice	1
Trichoptera	Caddisflies	10
Total		2111

Source: Adapted from Jongema (2017).

Some of the world's most popular insect foods are caterpillars (including mopane worms, *Imbrasia belina*),

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locusts (various Orthoptera species, per Egonyu *et al*, 2021), palm grubs (also called palm weevils, *Rhynchophorus* spp.) and stink bugs (Pentatomidae) (Dufour & Sander, 2000; van Huis *et al*, 2013). All are relatively big and can be gathered in large quantities. Insects are often eaten in immature stages, when they tend to be soft and rich in fat (Dufour & Sander, 2000). Adult wings, legs and exoskeletons are made of chitin, which is impossible to digest (Tang *et al*, 2019; Egonyu *et al*, 2021). Insects are more commonly eaten in the tropics, in part because of the greater biodiversity in the tropics (Lesnik, 2019). Some groups

of invertebrates are reported to be eaten in volumes great enough to influence human nutrition, food security, livelihoods or trade on a large scale.

Knowledge and public awareness of edible invertebrates has expanded greatly in the last few decades, but there are still major gaps in understanding of the range of species consumed, where they come from, how they are produced, their importance to nutrition and income generation, and the scale and importance of their trade at all scales from local to international.

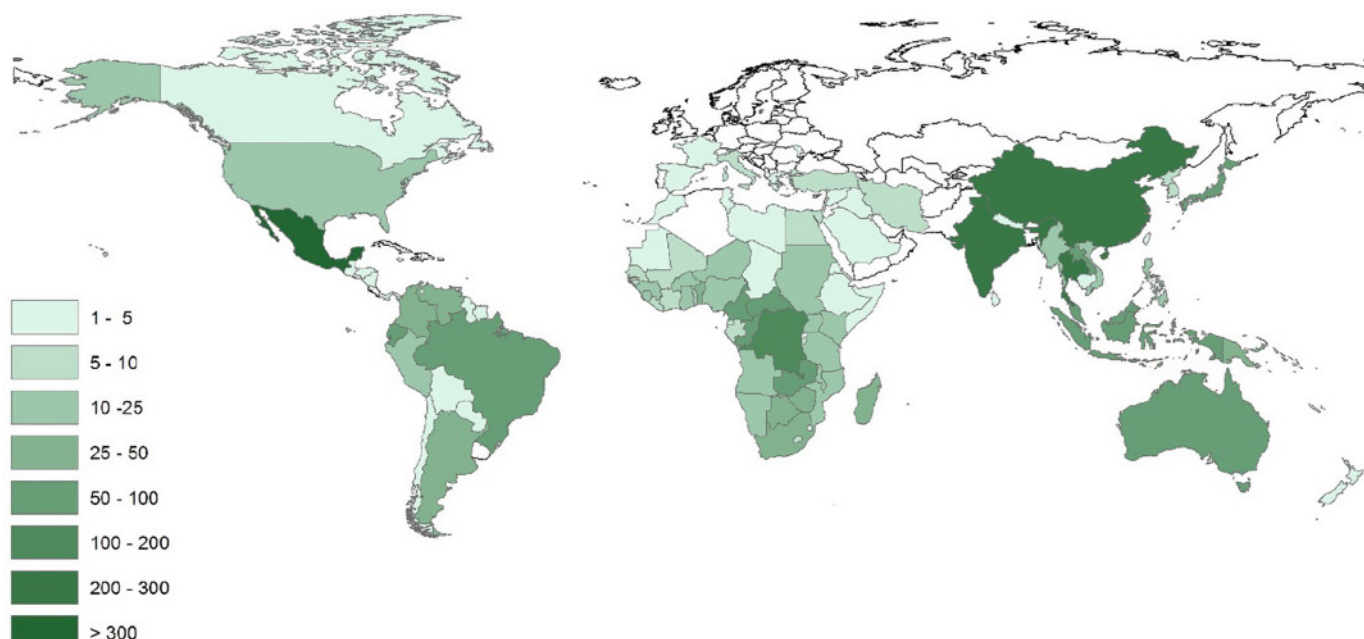


Figure 1. Recorded edible insect species, by country

(Source: Centre of Geo Information by Ron van Lammeren, Wageningen University, based on data compiled by Yde Jongema, 2017 (version 170402). Reproduced with permission.)

Wild harvesting versus insect farming

Invertebrate farming has increased since the mid-2010s: reared by family farmers from Cameroon (giant African snails) to the USA (mostly crickets) to Thailand (crickets, silkworm pupae and others). Improved rearing technologies have allowed large facilities to be built worldwide, especially in temperate countries, to rear a handful of species for food: for example, house crickets (*Acheta domesticus*) and field crickets (*Gryllus bimaculatus*). Yellow mealworms (*Tenebrio molitor*) are reared as food for humans and as animal feed. The black soldier fly (*Hermetia illucens*) is reared as an environmentally friendly feed for livestock and fish in North America and Europe, and on a smaller scale in East Africa and South America (van Huis, 2022a).

Insect farming is providing an alternative to the use of fishmeal, easing pressure on our overexploited oceans. Farmed insects can also replace some of the soy grown

on land cleared from forests, especially in South America. The species farmed, such as black soldier fly, are chosen because their production can be mechanised, they can be fed on cheap substrates, they have market potential and they can be protected from diseases (*ie* entomopathogens) (van Huis, 2022b). Since 2000, smallholders have started to farm a few of these species of insects and snails, and industrial-scale production of insects as feed is now developing rapidly. The quantity, nutritional quality and safety of insects relies greatly on their feed intake. Tropical forages (grasses and legumes) can provide a valuable and yet untapped source of feed for several farmed insect species (Buitrago Espitia *et al*, 2021). Black soldier fly larvae can convert a wide range of organic waste into food and feed, but this refuse may be contaminated with heavy metals, chemicals and pathogens, including some that are resistant to antibiotics, which is a safety concern.

Many insects are semi-cultivated. The Aztecs placed bundles of leaves in lake waters to encourage several genera of aquatic Hemiptera to lay their eggs

(*ahuautle*), a delicacy which the Spaniards later called 'Mexican caviar'. The lake habitat was destroyed by pollution in the 20th century (van Huis *et al*, 2013). The insects are now induced to lay their eggs on artificial lakebed nurseries in clumps of grass inserted into the shallow lake bottom (van Huis & Oonincx, 2017).

Threats and risks

Countries, scientists and conservationists often report the threat of overharvesting – extracting unsustainable volumes of individuals of a given species – but this alarmism is not always supported by scientific evidence. The most damaging overexploitation often includes using inappropriate harvesting practices, such as cutting down trees to gather caterpillars, which degrade habitats.

Wild species that are gathered for sale and cannot be farmed are probably at the greatest risk. Threats to their biodiversity stem from habitat loss, environmental degradation (urbanisation, deforestation, pollution, *etc*), climate change, and the loss of traditional knowledge on which species to collect and how to harvest them properly. Wild harvesting may also transfer diseases between insect populations, if pathogens are carried on the boots and equipment of collectors (Berggren & Low, 2024).

Overharvesting in nature has led to declining populations of witchetty (witjuti) and bardi grubs and honey ants in Australia. Anthropologist Alan Yen noted that "better access" (probably cars and roads) allowed overharvesting by indigenous people, in part for the ecotourism and restaurant markets (Yen, 2009). An unknown number of edible species face some kind of threat from overharvesting or environmental change. For example, edible insects with small populations which are harvested in their juvenile stages, can suffer population loss and even risk extinction (Cerritos, 2009). In the miombo woodlands of Angola, Malawi, Mozambique, the United Republic of Tanzania and Zimbabwe, over 30 species of caterpillar (mostly Saturniidae) are harvested and eaten. Many species have become locally extinct due to forest clearing, burning and overgrazing (Kenis *et al*, 2006).

A few species of agricultural pests (eg grasshoppers and locusts) are extremely abundant and can be wild harvested with little threat to their populations. However, even abundant insects can become extinct, for example the Rocky Mountain locust (*Melanoplus spretus*) which once blanketed the shores of the Great Salt Lake in Utah, was extinct by 1900, due to Anglo-American settlers converting the montane river valleys to agriculture after 1847 (Lockwood, 2010).

About 40 percent of the world's insects could be extinct in the next few decades. Lepidoptera, Hymenoptera and

dung beetles (Coleoptera) are the most affected, whereas four major taxa (Odonata, Plecoptera, Trichoptera and Ephemeroptera – which are aquatic in their larval stages) have already lost many species (Sánchez-Bayo & Wyckhuys, 2019). In north-east India, one of 31 edible insects species in Loktak Lake, the giant water bug (*Lethocerus indicus*), was once abundant in rice fields, on the lake shore and in local markets. This water bug is now disappearing because of pollution from chemical fertilisers and pesticides (van Huis & Oonincx, 2017).

Commercialisation can lead to overharvesting of wild populations, as has happened with the mopane caterpillar in Africa since the 1990s. Once commercial demand starts to stimulate sales of wild invertebrates, the populations may be overharvested, ignoring local knowledge. For example, overeager collectors may chop down mopane trees for quick access to the mopane caterpillar (Illgner & Nel, 2000; van Huis *et al*, 2013). In the Democratic Republic of the Congo, clearing and burning secondary forest to plant crops kills those edible caterpillars that pupate in the soil, and this is likely to increase as fallows shorten (Ombeni *et al*, 2022). Wild snail populations in West Africa have also declined, not just from harvesting, but also due to deforestation, pesticide use, slash-and-burn agriculture and the collection of immature snails (Cobbinah *et al*, 2008).

Conservation measures

There is a need for well-informed regulation of commercial wild harvesting and for better conservation of wildlands where edible invertebrates are found. As with many conservation measures, concrete evidence of the effectiveness of these approaches is unavailable or difficult to find. In Tulancingo, a community near Mexico City, the indigenous people once harvested 30 species of insects from five orders. For example, *escamoles*, ant larvae and pupae (*Liometopum apiculatum*), were once harvested by expert "*escamoleros*", local men who knew how to dig into the nests and remove *some* of the *escamol* and then close the nest. In the absence of regulations, clumsy outsiders, seeking to supply the lucrative restaurant trade, simply dug up the nests, destroying them and are driving this ant species close to local extinction (Ramos-Elorduy, 2006).

Formal protected areas are an option. For example, there are a few formally protected areas for threatened butterflies in South Africa. Protected areas often target larger animals for conservation, but edible insects such as beetles, stinkbugs, caterpillars, locusts and termites are also found in these refuges and may benefit by accident rather than by design. The Kruger National Park in South Africa has issued permits since 1994 to harvesters who collect mopane caterpillars so that local people can benefit from the park (Dzerefos, 2018).

In Australia, a strategic approach, engaging the public, documenting traditional foods and using 'flagship species' has been adopted to improve the conservation of insects, arachnids and crustaceans, including 204 species classified as threatened (Taylor *et al*, 2018). 'Flagship species' are not necessarily threatened but are of special scientific or social interest. Highlighting the flagship species generates interest and engagement with scientists and local communities to protect threatened invertebrates in general. Some of the proposed flagship species are edible, including the weaver ant (*Oecophylla smaragdina*) and the honey-pot ants (*eg Camponotus inflatus*) (Taylor *et al*, 2018).

Conservation efforts depend on identifying biodiversity hotspots and protecting them (León-Cortés *et al*, 2023). In Thailand, the Government is making efforts to protect its insect populations through the conservation of forests and natural areas (Halloran *et al*, 2015). This includes national regulations to prohibit harvesting of wild beehives in the forest, but the regulations are poorly enforced. Poor, unemployed bee hunters depending on the income, not recognising their impact, continue to collect and sell whole hives of wild native bees (*Apis dorsata*, *A. florea*, *A. andreniformis*, *A. cerana* and *Trigona* spp.) to meet wild honey demand from consumers (Boongird, 2010). In sum, regulations are of little use unless they are enforced, consumers should be sensitised about the wild products they buy, and some insect collectors need alternative sources of livelihoods.

The effort to mass produce insects to replace fish and soy in animal feed is just getting started. But this research and development is important to protect our oceans and South American forests, which are now being rapidly converted to soy farming for global markets. No doubt more data on biodiversity impacts will emerge as the industry matures.

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