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Review

Bee and non-bee pollinator importance for local food security

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Pollinators are critical for food security; however, their contribution to the pollination of locally important crops is still unclear, especially for non-bee pollinators. We reviewed the diversity, conservation status, and role of bee and non-bee pollinators in 83 different crops described either as important for the global food market or of local importance. Bees are the most commonly recorded crop floral visitors. However, non-bee pollinators are frequently recorded visitors to crops of local importance. Non-bee pollinators in tropical ecosystems include nocturnal insects, bats, and birds. Importantly, nocturnal pollinators are neglected in current diurnal-oriented research and are experiencing declines. The integration of non-bee pollinators into scientific studies and conservation agenda is urgently required for more sustainable agriculture and safeguarding food security for both globally and locally important crops.

Highlights

One-third of pollination studies focus exclusively on bees, introducing a potential bias in their importance for crop yield.

Non-bee pollinators can have relatively high importance for local crops with cultural and food values.

Nocturnal pollinators were commonly cited as critical pollinators of locally important tropical crops; however, their contribution is neglected in crop pollination studies.

The general decline of non-bee pollinators calls for an urgent conservation agenda for not only buffering the alarming global loss of biodiversity, but also safeguarding food security and local livelihoods.

Contribution of bee and non-bee pollination services to human well-being

Worldwide, nearly 90% of wild flowering plant species depend to some degree on animal-mediated pollination for reproduction [1,2], including a broad range of crop species [3,4]. **Crop yield** (see Glossary) and crop quality of more than three-quarters of the leading global crop types depend on animal pollinators to some degree [3,4], accounting for 5–8% of global crop production [5]. Many fruit, vegetable, seed, nut, and oil crops are pollinator dependent, supplying major proportions of micronutrients, vitamins, and minerals to the human diet [4,6]. Furthermore, the reliance of agriculture on pollinator-dependent crops has increased in volume by more than 300% over the past five decades [5], and pollination limitation due to a lack of pollinators is a common cause of lower crop yield [3,7,8].

A diverse community of pollinators generally provides more effective and stable crop pollination than any single species [8]. Pollinator diversity, including non-bee species, such as flies, wasps, beetles, butterflies, and moths, contributes to crop pollination even when managed species (e.g., the Western honey bee *Apis mellifera*) are present in high abundance [8]. Overall, it is estimated that non-bee insects perform 25–50% of the floral visits of globally important crops [9]. Moreover, crop fruit set increased with non-bee insect visits independently of bee visits, highlighting the complementary role of non-bee pollinators in crop pollination [9,10]. In addition, the floral structure and blooming activity (e.g., diurnal vs. nocturnal bloom) of many cultivated plants can restrict the mutualistic interaction to mostly non-bee pollinator species. This is important for some crop species with a high value on the global market [9]. However, it is especially important for other minority crops that are very valuable to local people (e.g., açai palm *Euterpe oleracea* and durian *Durio zibethinus*).

While similar stress factors are expected to impact bees and non-bee pollinators [2,11–14] alike, over the past few decades, more effort has been put into assessing global trends of increasingly

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decimated bee populations [4], than similar trends of declining non-bee pollinators and their associated pollination services [9,10,15,16]. Here, we reviewed the role, diversity, and conservation of non-bee species in crop production. In addition to assessing the broad range of crops visited by non-bee species, we evaluated their overall role in supporting **food security**.

Role and diversity of bee and non-bee pollinators in crop production

Bees have traditionally been considered the most important group of crop pollinators worldwide [3,17]. Their pollinating efficiency is linked, among other things, to: (i) their diet comprising predominantly resources derived from flowers [18]; (ii) their bodies covered with branching hairs, which allow for efficient attachment and transport of pollen grains; and (iii) their floral fidelity to a given species during the same foraging trip or even during their lifetime [19,20]. However, recent studies highlight the important contribution of other non-bee insects in crop production, such as flies, butterflies, moths, wasps, beetles, thrips [9,21], as well as other groups, such as mammals or birds [22,23]. For example, Rader *et al.* [9] explicitly evaluated the role of non-bee insects on crop pollination. They found that flowers of all analyzed crops ($N = 20$) were visited by both bee and non-bee insect species, suggesting that the role of non-bee pollinators has been overlooked. However, these studies focused mainly on crops important for global trade, potentially excluding crops of local importance for food production.

We extensively searched the published literature to gather data on bee and non-bee floral visitors considered as pollinators (while a pollinator, *sensu stricto*, is a floral visitor that deposits pollen and contributes to flower fertilization) in crop production using the Web of Knowledge[i] (see Section S1 in the supplemental information online). We selected articles that published original data on the diversity of pollinators visiting crops with local importance for people (i.e., fruit and/or seeds of considerable economic, nutritional, and cultural value for local communities; Box 1) or of global market importance (i.e., the crop produced is mainly exported and, thus, present in the FAOSTAT database[ii]), which produced 154 studies (see Section S1 in the supplemental information online for more details on the literature search methodology). For each study we recorded: (i) the study country of origin; (ii) the crop species, and whether its production was of importance for the global market or for local people; and (iii) the sampling method used to estimate the abundance and diversity of floral visitors. Interestingly, we found that, depending on the sampling method used, 67 studies (44%) focused only on bees as crop pollinators and, thus, did not assess the diversity of pollinators visiting crops. This can introduce a methodological bias of the importance of bees for crop pollination, which is currently questioned relative to the contribution of other insect pollinators [9,10]. Therefore, we excluded these 67 studies from the analysis.

Overall, the data set comprised 83 crops, with 31 crops described as important for global food markets, 48 crops described as important for local people, and four crops described as both

Box 1. Global and locally important crops

Crops of global importance are defined as those crop species that were mainly produced for exportation on the global market. The trade of these crops is regulated by stock exchanges and international organizations, such as the World Trade Organization. Therefore, these crops are listed in the FAOSTAT database[ii] (e.g., coffee *Coffea arabica*, oilseed rape *Brassica napus*, and strawberry *Fragaria* × *ananassa*). Conversely, crops of local importance to people are defined as fruits and seeds of considerable economic, nutritional, and cultural value for communities. For instance, production is consumed directly by these communities, or has high cultural value due to the perpetuation of traditional agronomic practices. Specifically, we categorized crops as of local importance when meeting one of the two following criteria: (i) crop species that do not appear in the FAOSTAT database (e.g., acai palm *Euterpe oleracea*, durian *Durio zibethinus*, and petai *Parkia speciosa*) or (ii) crop species that appear in the FAOSTAT database but authors of the original papers from which pollinator information was gathered explicitly considered the target crop species as important for local people (e.g., papaya *Carica papaya* in Thailand [61], banana *Musa acuminata* in Thailand [57] and common bean *Phaseolus vulgaris* in Tanzania [74]; see Table S1 in the supplemental information online).

Glossary

Crop yield: defined by the Food and Agriculture Organization (FAO) as a numerical measure of a harvested crop per unit area of land on which it is grown.
Ecosystem services: term popularized by the Millennium Ecosystem Assessment; refers to the ecological processes which benefit human societies. Ecosystem services are divided into four categories: provisioning services (e.g., crop pollination), regulatory services (e.g., climate regulation), cultural services (e.g., recreational interactions with nature), and supporting services (e.g., nutrient cycling).
Food security: according to FAO, food security exists when '… all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' [75].
Orphan crops: underused, lost, indigenous, minor, promising, or future crops in a state of neglect and abandonment despite their grossly underexploited food and nutritional potential that can contribute to food and nutrition security.

globally and locally important crops (avocado *Persea americana*, blueberry *Vaccinium* sect., common bean *Phaseolus vulgaris*, and fennel *Foeniculum vulgare*; see Table S1 in the supplemental information online). The synthesis covered 39 countries (Figure 1). We then classified the diversity of pollinators across 12 taxonomic groups, including bees and nine groups of non-bee insects: Blattodea, Diptera, Coleoptera, Hemiptera, non-bee Hymenoptera, Lepidoptera, Neuroptera, Odonata, and Orthoptera, but also two groups of vertebrates: bats and birds. Overall, bees were the most common crop floral visitors (accounting for 91% of pollinator occurrences in all crops), followed by other insects, such as Diptera (67%), Lepidoptera (i.e., butterflies and moths, 44%), Coleoptera (33%), non-bee Hymenoptera (i.e., wasps and ants, 25%), and Hemiptera (18%). Blattodea, Neuroptera, Odonata, and Orthoptera were observed less than 2% of the time overall; thus, we excluded these groups thereafter.

Bees have been shown as the dominant group of pollinators visiting the majority of global food market crops [9,10], however, these results could be biased by the sampling methods that are commonly used. Indeed, we found that a large number of studies focused exclusively on bee sampling (44%). Moreover, only 31% of the pollination studies focusing on globally important crops had no species-specific restrictions on their sampling method. All these studies recorded non-bee and non-Diptera species as floral visitors, suggesting that pollination mediated by commonly overlooked animal groups could be more frequent than previously reported. For instance, we found that non-bee pollinators routinely visit several crops of global importance, including cocoa (*Theobroma cocoa*), coffee (*Coffea arabica*), common bean, onion (*Allium cepa*), sunflower (*Helianthus annuus*), and apple (*Malus domestica*) (Figure 2A).

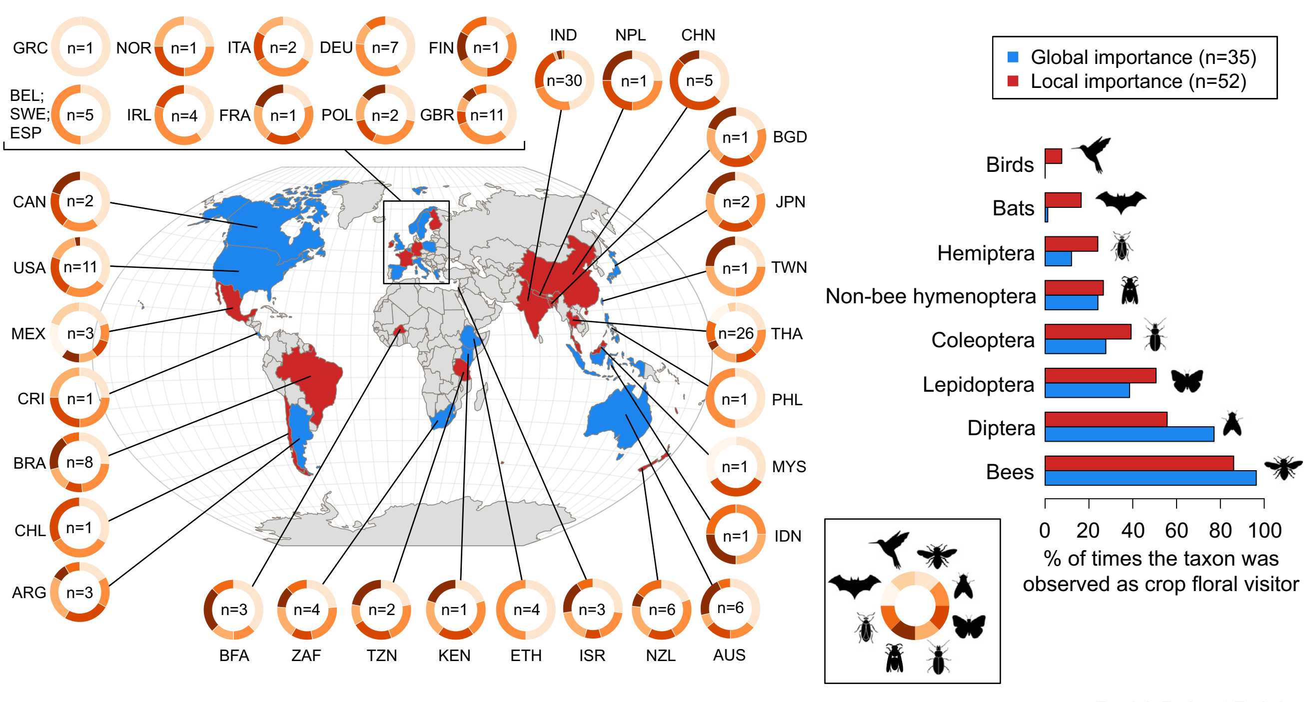

Figure 1. Global synthesis of crop pollinators reveals shared high-level diversity of non-bee species, including not only Diptera, Coleoptera, Lepidoptera, non-bee Hymenoptera, Hemiptera, but also non-insect pollinators, such as bats and birds, with differences between species groups for crops with global food market importance and those of importance for local people. *N* represents the number of monitoring studies per country. Countries are colored according to the density of globally versus locally important crops (e.g., countries in blue whenever two-thirds of the crops studied are of global importance). Acronyms show the country names following the abbreviation ISO 3166 ALPHA-3. Icons used from www.freepik.com.

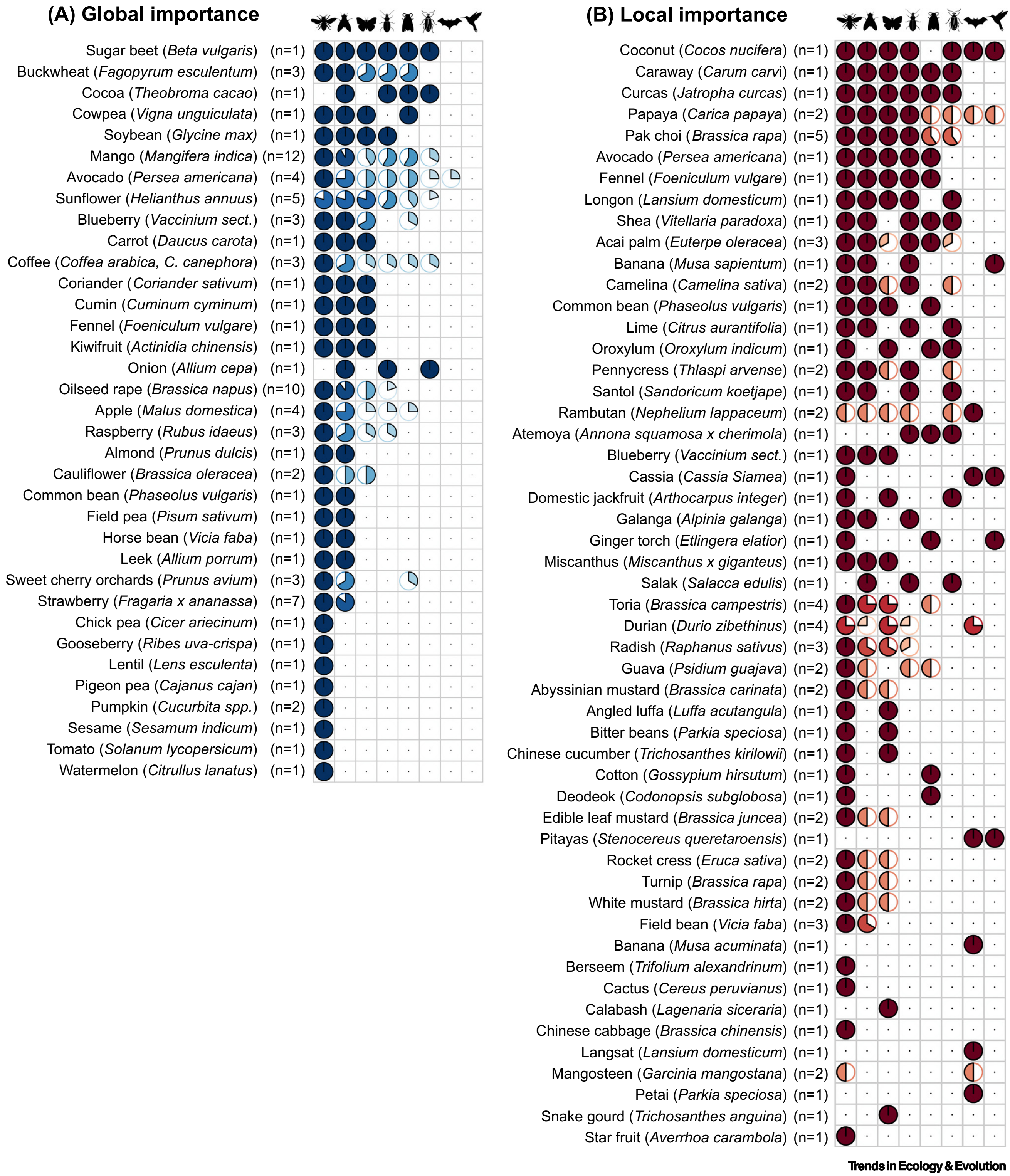

Figure 2. List of crops with (A) global food market importance or (B) importance for local people, and their observed species group of floral visitors, including Diptera, Coleoptera, Lepidoptera, non-bee Hymenoptera, Hemiptera, bats, and birds. Pollinator symbols follow Figure 1. Color gradient in the pie charts represents the density of floral visitors for which several studies were available. Icon used from www.freepik.com.

Although the diversity of non-bee insects confirms the results of Rader *et al.* [9], we show that non-bee pollinators are also more frequent floral visitors of locally important crops (Figure 1) and sometimes the only floral visitors (e.g., atemoya *Annona squamosa* × *cherimola*; salak *Salacca edulis*; pitayas *Stenocereus queretaroensis*; banana *Musa acuminata*; calabash *Lagenaria siceraria*; langsat *Lansium domesticum*; petai *Parkia speciosa*; and snake gourd *Trichosanthes anguina*; Figure 2B). Hence, our results suggest that supporting the yield of locally important crops cannot rely exclusively on bee pollinators. Floral visitors of such locally important crops also included non-insect species, such as bats (9%) and birds (4%), which can represent more than 30% of floral visits in tropical crops (e.g., in Malaysia and Mexico; Figure 1). Furthermore, the floral visit frequency by Diptera, Coleoptera, Lepidoptera, non-bee Hymenoptera, and Hemiptera is also higher in locally important crops compared with globally important crops, while pollination by bats and birds is mainly related to locally important crops (Figure 1). For instance, bats and birds are frequent visitors of several tropical crops for which bees have never been observed (e.g., pitayas, banana, langsat, and petai; Figure 2). Therefore, despite bees being dominant as pollinators in many studies, and disregarding the bias, non-bee pollinators can have an important role in local food security. This calls for consideration of local food crops and their pollinators in developing conservation programs to enhance **ecosystem services** for food security.

Nocturnal pollinators are neglected

Bats were found as nocturnal pollinators in several tropical crops, but some insects also provide this service (Figure 1) and their contribution remains understudied on crops of local and global importance [24]. In the recent CropPol global database on crop pollination recording insect pollinators of global crops [25], we focused on night-active Lepidoptera and Coleoptera [26,27] among those identified to, at least, the family level (restricted to 77% of the records). We identified 27 coleopteran and six lepidopteran species as potential nocturnal pollinators of oilseed rape, sunflower, ridge gourd (*Luffa acutangular*), and bottle gourd (*Lagenaria siceraria*) (Table 1). To assess the possible pollinating role of these insects, we analyzed the visitation rate of flowers by night-active Lepidoptera and Coleoptera in the CropPol database. We identified three species as potential nocturnal pollinators of sunflower: *Lampyris noctiluca* (Coleoptera, Lampyridae), *Lagria hirta* (Coleoptera, Tenebrionidae), and *Hyles euphorbiae* (Lepidoptera, Sphingidae) [25]. However, identification of nocturnal pollinators is limited because many of the coleopteran and lepidopteran pollinators listed in the CropPol database are only identified to higher taxonomic levels. Thus, CropPol potentially underestimates the contribution of nocturnal pollination. For instance, this global database does not record nocturnal pollination of apple and cucurbits; however, recent exclusion experiments showed that the contribution of nocturnal pollinators to pollination is significant [28–30].

The underestimation of nocturnal pollination is likely related to current diurnal-oriented research; common sampling techniques used to date are not adapted to the study of nocturnal pollinators. As an example, we analyzed the effectiveness of insect sampling techniques to record nocturnal pollinators in the CropPol database (i.e., the 27 coleopteran and six lepidopteran species) (Figure 3). Overall, five sampling techniques are commonly used either as passive 24 h-day sampling (e.g., pitfall trap and pan trap or bee bowl) or active daytime sampling (sweep net, focal observations, and transects). Pitfall traps are efficient for collecting night-active coleopteran pollinators, but fail to collect lepidopteran pollinators. Other passive 24 h-day sampling techniques show few records of both coleopteran and lepidopteran pollinator species. Interestingly, the active daytime sampling techniques are able to record nocturnal pollinators, in particular those of crepuscular activities, with higher efficiency in recording lepidopteran pollinators compared with coleopteran pollinators (Figure 3). However, all of these common diurnal-oriented research techniques are

Table 1. List of pollinators with crepuscular or nocturnal activities in crops based on the pollinator CropPol global database [25]

Order	Crop	Species or family		Refs
Coleoptera	*Brassica napus*	*Abax parallelepipedus*	*Nebria brevicollis*	[31,76,77][b,c]
		Agonum muelleri	*Nebria salina*	
		Amara similata	*Notiophilus aestuans*	
		Anchmenus dorsalis	*Notiophilus palustris*	
		Bembidion obtusum	*Platynus assimilis*	
		Bembidion tetracolum	*Poecilus cupreus*	
		Carabus granulatus	*Pterostichus anthracinus*	
		Carabus monilis	*Pterostichus melanarius*	
		Carabus nemoralis	*Pterostichus nigrita*	
		Clivina fossor	*Pterostichus vernalis*	
		Harpalus affinis	*Stomis pumicatus*	
		Harpalus rufipes	*Trechus quadristriatus*	
		Loricara pilicornis	Elateridae spp	
	Helianthus annuus	*Lagria hirta*[a]	Lathrididae spp	[c]
		Lampyris noctiluca[a]		
Lepidoptera	*Brassica napus*	*Pieris brassicae*	Pieridae spp	[26,78,79]
		Plutella xylostella	Sphingidae spp	
		Noctuidae spp		
	Helianthus annuus	*Eudalaca exul*	*Utetheisa pulchella*	[26,80][d]
		Hyles euphorbiae[a]	Noctuidae spp	
	Lagenaria siceraria	Noctuidae spp	Sphingidae spp	[26,79]
	Luffa acutangula	*Melanitis leda*	Sphingidae spp	[26,79,81]

[a]Species with a potential role of pollinator of the crop since they were collected in sessions where the visitation rate of their order was strictly greater than zero.
[b]www.ukbeetles.co.uk
[c]www.coleoptera.org.uk
[d]www.eol.org

limited in their robustness to measure pollination activity at night. The few techniques that ensure the accurate monitoring of nocturnal pollinators imply the observation of flowers at night [31]. Moreover, the use of camera traps is a promising option to collect diurnal and nocturnal information [32] to better understand and reconsider the role of nocturnal pollinators in crop production [33].

Importance of non-bee pollinators for local food security

Pollinator-dependent species encompass many fruit, vegetable, seed, nut, and oil crops, which supply major proportions of micronutrients, vitamins and minerals to the human diet [34–36]. Therefore, pollination directly benefits rural people who gain both their food and income from agriculture [2,37]. This is of particular importance for low-income families who lack access to marketed food, and where animal-pollinated crops contribute to a large part of their vitamin intake [38].

Most food is produced on a small scale by family farmers and traded locally or regionally, whereas ~15% is traded globally[ii]. Therefore, these locally produced crops can be equally, if not more, important for food security [39]. Given that locally produced crops can substantially contribute to food security, especially for the poorest and most rural people, there is a potential significant connection between pollination, local production, and food security [36]. For example, in several

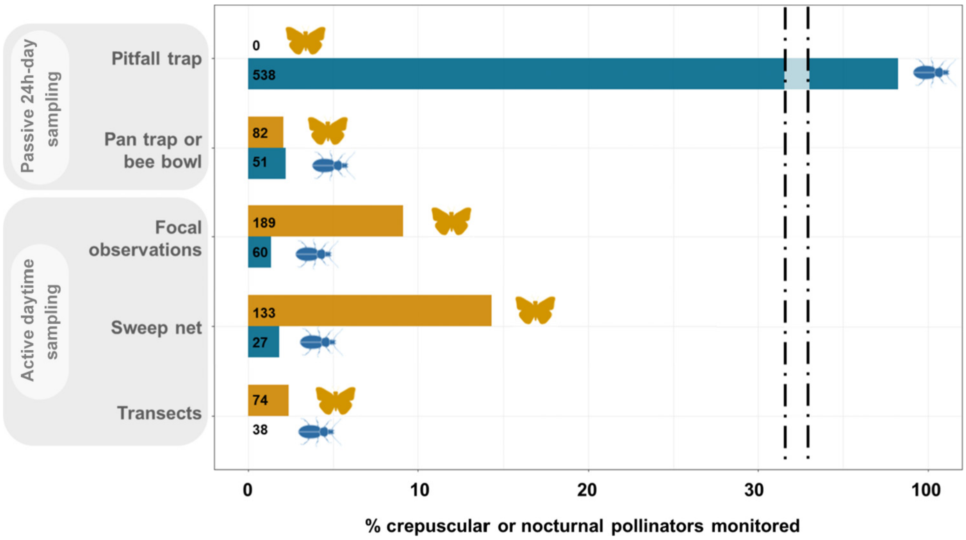

Figure 3. Methodological bias of common sampling techniques for monitoring crepuscular or nocturnal pollinators based on the pollinator CropPol global database [25]. Bars represent the proportion of crepuscular or nocturnal pollinators recorded among the total lepidopteran and coleopteran pollinators depending on the sampling methods. Numbers in the bar chart represent the total number of combinations (study × monitoring site × pollinator) for which we were able to determine that the species or family exhibited diurnal, crepuscular, or nocturnal activities. Icons used from www.freepik.com.

countries, such as Brazil and Mexico, poor and rural people rely heavily on pollinator-dependent crops [40].

Non-bee pollinators can also be relatively more important for local livelihoods than for globally traded crops overall. Although complementary pollination systems exist, in which both bee and non-bee species simultaneously have an important role in crop production [8,9], some crops are almost exclusively pollinated by non-bee species (Figure 2B) [9,10], as is the case for atemoya, banana, calabash, langsat, petai, pitayas, salak, and snake gourd, which are important crops for local production and economies. Certain non-bee pollinated crops are both globally and locally important. Cocoa is an emblematic example of a non-bee pollinator-dependent crop [41], which also requires cross-pollination to produce viable seeds [42]. The majority of cocoa pollination studies suggest that ceratopogonids (Diptera) are the most common and main pollinators [43–46]. Beyond the global importance of this crop, the World Cocoa Foundation estimated the number of people who depend on cocoa farming for their livelihood is 40–50 million worldwide [47]. Exports of cocoa products overall generated US$20.7 billion [48], with more than 4.7 million tons produced in 2017 [49]. Another example, less systematically studied, is African oil palm (*Elaeis guineensis*). This tropical crop is grown mainly to produce palm oil, which is obtained from the seeds and fleshy pulp of palm fruits. Although it is native to West Africa, cultivation has spread throughout the tropics and it is the most cultivated and traded vegetable oil in the world. Its low price and the fact that it can be used for many purposes (e.g., cooking oil, cosmetic product base, conservation method for processed food, or as biofuel [50]) have contributed to its popularity. Although palm oil can be pollinated by wind in dry environments, high crop yields depend almost exclusively on pollination mediated by a subfamily of weevils (Derelominae) among which species of the genus *Elaeidobius* are the most efficient pollinators [51]. Crop yield has been historically higher in plantations located within the areas where the weevils are native and abundant (e.g., Cameroon).

The New World leaf-nosed bats (Phyllostomidae) and the Old World fruit bats (Pteropodidae) provide unique and valuable pollination services to several crop species of local and global importance [52]. For example, most species of the genus *Agave* (Asparagaceae) are heavily dependent on phyllostomid bats for seed production [53], which are usually produced for selling. For their part, pteropodid bats are critical pollinators of several important commercial food species, such as the honeytree (*Madhuca longifolia*) in India [52], or petai [54] and durian [55,56]. In Southeast Asia, other locally consumed food and fiber plants depend on non-bee pollinators [57]. Vertebrates, such as birds, and especially bats, have an important, and often overlooked, role in tropical crop pollination [58–60]. Bats may be the main pollinators for up to 1000 species of plants across the tropics, including many of socioeconomic importance, such as durian, mango, and pitayas [58,61,62]. Additionally, wild plants sometimes have an important role in guaranteeing food security, especially in times of crop failure. For instance, the miombo ecosystem of southern Africa contains over 150 species of edible plants, which contribute to both nutrition and income [63], and several of which (e.g., *Kigelia africana*) rely significantly on bats for pollination [64,65].

If estimations of the importance of pollination services have mainly focused on globally traded crops, the importance of pollinators for local food security has likely been underestimated, especially the contributions of non-bee pollinators. Therefore, it is important to make sure that locally produced, noncommodity crops are not overlooked when estimating pollination dependence for food and nutritional security. This is also applicable for **orphan crops** and underutilized crops, many of which are thought to depend on animal-mediated pollination [63,66] and are recognized as important for food security [63,67,68]. The lack of knowledge as to what extent, not only non-bee pollinators, but also pollinators in general, contribute to local and regional crops, important for food security, is a call for future studies on these issues.

Conservation status of non-bee pollinators

Due to the expansion of anthropogenic activities, animal–plant interactions, including pollination, are in decline globally. IUCN Red List assessments indicate that many of the non-bee pollinator species are threatened, including 16.5% of vertebrate pollinators, which increases to 30% for island species, [55]. Regan *et al.* [56] calculated that 10% and 6% of the described birds and mammal species, respectively (1089 birds and 343 mammals) act as pollinators. In general, pollinating birds and mammals are slightly less threatened compared with non-pollinator birds and mammals, except for bats. Pollinating bat species are more threatened compared with non-pollinating species. In particular, bat populations are severely threatened in many parts of the world, and 80% of bat species require conservation actions [69]. The abundance and diversity of butterflies have also declined in northwest Europe and North America [2] and general insect declines have been widely reported [70]. Overall, the lack of information on population trends of many pollinators is especially worrying [71].

Concluding remarks and future perspectives

Non-bee species are common floral visitors to crops of global and local importance. For certain crops, non-bee species are the primary, often specialized, pollinators (e.g., banana, calabash, langsat, petai, and snake gourd). For example, bats and birds are common pollinators of tropical crops for which bees have never been observed visiting flowers. For other crops, non-bee species contribute by enhancing the abundance and diversity of floral visitors. Pollination provided by a wide range of taxa is expected to confer crop stability in the short and long term, because they are functionally complementary (e.g., different floral visitors might be active under different weather conditions).

Non-bee species are critical contributors to food production as pollinators, not only for locally important crops, but also for other ecosystem services. Given their particular life-history traits,

Outstanding questions

What is the contribution of nocturnal pollination provided by non-bee animals to crop production? The role of nocturnal pollinators is often overlooked in pollination studies, in particular for global food market crops. However, certain nocturnal pollinators, in particular bats, are known to contribute to pollination of crops such as banana and mango.

Is the demand for pollination services provided by non-bee species increasing? The global increase in the production of pollinator-dependent crops raises the question of the identity of the pollinators able to provide pollination services to these crops, since managed honey bees are not always the optimal solution. Indeed, pollinators vary in pollination efficiency and more diverse pollinator assemblages are known to provide better crop pollination services compared with single-species assemblages.

Are non-bee pollinators more resilient to anthropogenic disturbances compared with bee pollinators? Bee pollinators are the focus of many studies and, thus, their responses to anthropogenic disturbances are relatively well understood, particularly in agricultural landscapes. However, because non-bee pollinators have not received the same attention, their resilience to these disturbances is not so well established.

What is the contribution of non-bee pollinators to the provisioning of additional ecosystem services (regulatory, material, and non-material) compared with bee pollinators? Beyond bees that exclusively feed on pollen and nectar during all their adult life stages, numerous non-bee pollinators, such as vertebrates or other insect taxa (e.g., beetles and ants), can be considered as potential biocontrol agents or seed dispersers as well as a source of inspiration for art, literature, religion, traditions, technology, and education. However, few studies focus on documenting the whole range of potential positive side effects of non-bee conservation in agricultural landscapes.

How much do locally important crops depend on different pollinator species, especially in the global south? Little is known about the species of pollinators that visit crops that benefit local communities, particularly in the global many non-bee pollinator species provide seed dispersal, pest control, or nutrient cycling (see Outstanding questions). Moreover, in local cultures, non-bee species act as sources of inspiration for art, music, literature, religion, traditions, technology, and education. Despite their importance, we found that non-bee pollinators are less studied compared with bee pollinators because sampling methods for floral visitors focus mostly on bees. In particular, the absence of sampling schemes for nocturnal pollinators is noteworthy [33]. In addition, most habitat restoration studies focus on bee species, while their impact on many non-bee floral visitors is unclear.

Non-bee floral visitors might respond differently to land-use change compared with bee species (see Outstanding questions). Certain groups of non-bee floral visitors, such as some Diptera species (e.g., hoverflies) appear to be more tolerant to anthropogenic pressures compared with bees, providing crop insurance in places where bee populations have declined [72]. Overall, however, non-bee species are not the exception to current biodiversity declines and are threatened all over the world. To revert the loss of non-bee contributions, current management of agricultural and forest landscapes needs to transition to systems that conserve both bee and non-bee pollinators [16]. Alternatives to conventional production systems, such as ecological intensification, already exist, with successful examples of applications found throughout the world [73].

south. However, some of these crops are known to attract interesting non-bee pollinator assemblages (e.g., bats and flies), which provide essential pollination services.

Declaration of interests

The authors declare no conflicts of interest.

Resources

[i]http://apps.webofknowledge.com/

[ii]www.fao.org/faostat/en/#data

Supplemental information

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