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INSECT POLLINATORS AND THEIR CHALLENGES: A REVIEW

Adugna Gindaba and M. Sadre Alam Fakhri*

Department of Plant Sciences, College of Agriculture and Veterinary Sciences, Ambo University, Ambo, Ethiopia, P. Box No. 19.

Corresponding Author: M. Sadre Alam Fakhri

Department of Plant Sciences, College of Agriculture and Veterinary Sciences, Ambo University, Ambo, Ethiopia, P. Box No. 19.

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ABSTRACT

Mutualisms between plants and their floral visitors sustain not only plant diversity, but also the diversity of an estimated 350, 000 animal species, mainly various insects, birds and mammals. Wild bees represent the most important group of pollinator insects because they play a key role in agriculture, pollinating almost all crop varieties. However, they are increasingly at risk of local and even global extinction. Climate change and habitat loss are affecting all major aspects of the biology of insects that pollinate plants in both natural and agricultural communities. Understanding network structure and its underlying causes are essential parts of any study of biodiversity and its responses to disturbances, yet it is a conceptual and methodological challenge to address these problems in highly diversified communities with thousands of interactions. Plant–pollinator communities are typically composed of a high number of plant species and an even greater number of pollinator species.

KEYWORDS: Wild bee, pollinator, climate change.

INTRODUCTION

Sexual reproduction of many crops and the majority of wild plants are dependent on animal pollination through insects, birds, bats and others, with insects playing the major role (Renner, 1998). The most common way plants attract animals to visit their flowers is by providing food such as nectar, pollen or oils. While searching for these rewards in the flower, pollen from the flower's anthers may stick to the body of the animal. When the animal visits subsequent flowers in search of more rewards, pollen from its body may adhere to the stigma of these flowers and again, new pollen may stick to the body of the animal. Insect pollination is a very important ecosystem service (Hoehn *et. al.*, 2008; Winfree *et. al.*, 2011) that provides essential support for food security and ecosystem stability (Lautenbach, 2012). Approximately 90% of the world's angiosperms require insect pollination (Klein *et. al.*, 2007), and 85% of agricultural crops have increased production with insect pollination (Winfree *et. al.*, 2011). The interaction between floral traits and pollinator behavior has been an important force in the co-evolution of plants and their animal pollinators. Mutualisms between flowering plants and animal pollinators are an integral ecological relationship of vital importance for both natural and agricultural ecosystems (Kearns *et al.*, 1998). Approximately 87.5% of flowering plants use animal-mediated pollination to set seed and fruit (Ollerton *et. al.*, 2011), corresponding to 70% of our agricultural crops (Klein *et. al.*, 2007). Therefore, in order to insure the security of our pollinator-dependent crop species, it is imperative to characterize the mechanisms and practices that can enhance pollinator ecosystem services in managed landscapes. At least 130,000 species of animal, and probably up to 300,000, are regular lower visitors and potential pollinators (Buchmann and Nabhan 1996; Kearns *et. al.*, 1998). There are currently about 260,000 species of angiosperms (Soltis and Soltis, 2004) and it has been traditional to link particular kinds of lowers to particular groups of pollinators. About 500 genera contain species that are bird pollinated, about 250 genera contain bat-pollinated species, and about 875 genera predominantly use abiotic pollination; the remainder contains mostly insect-pollinated species, with a very small number of oddities using other kinds of animals (Renner and Ricklefs, 1995).

Flowers differ tremendously in color, scent, size and shape; and they are visited by an equally diverse morphological and taxonomic array of animals. The most common flower visitors are insects belonging to the orders Hymenoptera, Lepidoptera, Diptera and Coleoptera. The objective of this review is to note importance and contributing factors for declining of pollinators.

Insect Pollinators and Their Important Role

Pollinators and other flower visitors utilize flowers for food in the form of nectar and pollen, and, in some cases, oils and resins, as well as for shelter and mating rendezvous sites (Simpson and Neff, 1983). Some pollinators also use flowers as brood sites (Hembry and Althoff, 2016). Thus, mutualisms between plants and their floral visitors sustain not only plant diversity, but also the diversity of an estimated 350, 000 animal species, mainly various insects, birds and mammals (Ollerton, 2017). The degree of ecological dependence of these animals on the flowers ranges from completely obligate, as in species that use particular flowers as brood sites or sources of food, to facultative, as in species that have generalist diets that include some food from flowers.

Cross-pollination is not only essential for seed production for around half of all plant species, but also results in higher seed production and performance of progeny in many self-compatible species (Aizen and Harder, 2007). This is because cross-fertilization reduces the likelihood of inbreeding depression which is commonly observed in the self-fertilized progeny of plants (Keller and Waller, 2002). Cross-fertilization also promotes the build-up of genetic variation and thus the ability of plant species to adapt to new and changing environments (Morran *et. al*., 2009). Studies involving supplemental hand-pollination of flowers have shown that seed production of plants is often limited by the quantity and quality of pollen received naturally (Knight *et. al*., 2005). This phenomenon of pollen limitation of fecundity occurs naturally in relatively undisturbed ecosystems, but is often exacerbated when plants populations become small and fragmented (Wilcock and Neiland, 2002). It can arise because pollinators are rare or because plants have too few mating partners and pollinators carry inadequate amounts or quality of pollen. Because self-incompatible plants cannot use their own pollen to produce seeds, they are more likely to experience pollen-limitation than self-compatible plants (Larson and Barrett, 2000). Approximately 73% of the world's cultivated crops, such as cashews, squash, mangoes, cocoa, cranberries and blueberries, are pollinated by some variety of bees, 19% by flies, 6.5% by bats, 5% by wasps, 5% by beetles, 4% by birds, and 4% by butterflies and moths (Freitas *et. al*., 2004). Of the hundred principal crops that make up most of the world's food supply, only 15% are pollinated by domestic bees (mostly honey bees, bumble bees and alfalfa leafcutter bees), while at least 80% are pollinated by wild bees and other wildlife (as there are an estimated 25,000 bee species, the total number of pollinators probably exceeds 40,000 species). Bees are the most effective pollinators of crops and natural flora and are reported to pollinate over 70% of the world's cultivated crops. It has also been reported that about 15% of the 100 principal crops are pollinated by domestic bees (i.e. manageable species e.g. hive-kept species of honeybees, bumble bees, alfalfa bees, etc.), while at least 80% are pollinated by the wild bees (Kenmore and Krell, 1998).

The role of wild bee in pollination

The term "wild bee" is used commonly for all bees except honey bees in the genus *Apis* (Abrol, 2012).Wild bees (order Hymenoptera: Apoidea) represent the most important group of pollinator insects because they play a key role in agriculture, pollinating almost all crop varieties. However, they are increasingly at risk of local and even global extinction due to climate change (Biesmeijer *et. al*., 2006), which can disrupt the overlap of flower production and pollinator flight activity (Wall *et al*., 2003). The major characteristic of climate change is an increase in the mean global temperature. Elevated temperatures are known to influence the foraging activity, body size at maturity, and individual lifespan (Scaven and Rafferty, 2013) of wild bees. The physiological impacts of climate warming might not have negative effects on individual insect pollinators; in fact, some could even have positive effects. Increases in mean temperature affect the diversity and abundance of wild bees in agricultural ecosystems.

The status of bees worldwide is currently a topic of research and conservation concern (Potts *et al*., 2010). Numerous factors may be threatening bees including habitat loss and fragmentation, pesticides, and disease (Winfree *et. al*., 2009). In addition, the increasingly widespread use of managed bees may have negative effects on wild bee populations (Goulson, 2003; Paini, 2004).

Managed bees, including honeybees, bumblebees and some solitary bees have become an integral component of agriculture due to a rising demand for pollinator-dependent crops and without which many farms would likely experience pollination deficits. However, the use of managed bees may negatively affect wild bee abundance or diversity, which could in turn impact food production since a diverse wild bee community has been found to increase pollination rates and subsequent crop yields even when managed bees are present (Klein *et. al*., 2003; Mallinger and Gratton, 2015) . Furthermore, in natural habitats, a diverse wild bee community is integral for maintaining plant diversity and ecosystem function (Memmott *et. al*., 2004; Fontaine *et. al*., 2005). Thus, identifying and quantifying the factors that affect wild bees is essential for bee conservation and to ensure pollination services within both managed and natural habitats. There are several ways in which managed bees could affect wild bees including through competition over finite resources such as nectar, pollen, or nesting habitat. Competition with managed bees for pollen and nectar may induce changes in wild bee floral use and niche breadth, with potential consequences for bee fitness. While the majority of wild bees are polylectic and potentially able to modify foraging behaviors in the presence of honey bees, competition could still have negative effects if wild bees are forced to forage on less nutritious plants, spend more time searching for flowers that are unoccupied or whose resources have not yet been depleted, or forage further from their nests (Fruend *et. al*., 2013; Spiesman and Gratton, 2016).

Factors for Insect Pollinators Decline

Global change is affecting insect pollinators in profound ways. Climate change and habitat loss are affecting all major aspects of the biology of insects that pollinate plants in both natural and agricultural communities, altering their distribution, phenology, abundance, physiology, and morphology (Burkle *et. al*., 2013).

Climate change

The responses of insect pollinators to climate change have been relatively well-studied, although much remains to be resolved. For the most part, experimental studies of climate change factors on insect pollinators have focused on temperature (Bennett *et. al*., 2015), an important determinant of developmental rate (Kingsolver and Huey, 2008). Manipulations of other factors, such as carbon dioxide (Hoover, 2012) or precipitation (Burkle and Runyon, 2016), have been applied to plants with subsequent measures of pollinator responses to altered floral traits. As climate changes, the habitats suitable for supporting pollinators may change with some areas being lost and others are being newly created. When a habitat disappears, or the pollinator is unable to move to a new habitat, then local extinction can occur (Travis, 2003). Climate change may also disrupt the synchrony between the flowering period of plants and the activity season of pollinators (Wall *et. al*., 2003).

Land-use change

Landscape configuration can play an important role in the maintenance of diverse pollinator communities. Decreased patch size, loss of habitat area and reduced connectivity have all been identified as important drivers of species richness declines (Marini *et. al.*, 2014). Furthermore, they negatively affect the ecological network link richness, leading to network contraction (IPBES, 2016). Pollinator richness generally declined with decreasing landscape heterogeneity (Andersson *et. al*., 2013) and habitat destruction and fragmentation are likely to negatively affect pollinators (Harris and Johnson, 2004). Areas where habitats are not completely transformed, such as heavy livestock grazing, can also negatively impact pollinators (Mayer, 2004), changing the dominant guilds (Colville *et. al.*, 2002), and thus ecological processes. Although livestock grazing is not often seen as a driver of fragmentation, grazing can reduce flower availability of palatable plants, leading to changes in seed set and demography (Mayer, 2004).

Habitat loss is generally thought to be the most important factor driving bee declines (Brown and Paxton, 2009). Winfree *et. al*. (2009) found a significant, but relatively small, negative effect, of various types of disturbance on wild bee abundances and species richness, of which habitat loss and/or fragmentation was the most important contributor. Ricketts *et. al*. (2008) also found a strongly significant negative effect of distance from natural habitat (due to habitat loss and/or conversion) on the richness and abundance of wild bees. Habitat degradation might affect bee species primarily by the loss of floral and nesting resources, and the introduction of insecticides with lethal or sub-lethal effects. The data on pollinator decline in Africa are scarce and only a few studies reporting on declines over a local scale are available (Pauw and Hawkins, 2011). In Africa, many species of pollinators are in Sub-Saharan Africa are found in forest habitats. Deforestation continues to occur on the continent (Keenan *et. al*., 2015). Reasons for deforestation are conversion of land for agriculture (Haines-Young, 2009), and use of timber for construction and fuel (IEA, 2016). Agricultural intensification has increased the use of agrochemicals, resulting in potential habitat degradation within agricultural areas. Insecticides can cause mortality by direct intoxication (Alston *et. al*., 2007) and can result in local shifts in wild bee diversity and abundance (Brittain *et. al*., 2010), whereas herbicides and fertilizers can affect pollinators indirectly by decreasing floral resource availability (Gabriel and Tscharntke, 2007).

Plant–Pollinator Networks

Within habitats, species and their interactions assemble into large, complex ecological networks. Such networks are rich in structural heterogeneity (Montoya *et. al*., 2006). Understanding network structure and its underlying causes are essential parts of any study of biodiversity and its responses to disturbances, yet it is a conceptual and methodological challenge to address these problems in highly diversified communities with thousands of interactions. The study of plant–pollinator networks is becoming an increasingly important field of research. Plant–pollinator communities are typically composed of a high number of plant species and an even greater number of pollinator species. For this reason, deciphering the structure of plant–pollinator interactions is important to understand co-evolutionary processes in species-rich communities (Bascompte and Jordano, 2007). At the same time, a good assessment of the structure of plant–pollinator interactions is essential to evaluate the stability of pollination systems. This is especially important in the face of reported pollinator declines associated with anthropogenic influence (Biesmejer *et. al*., 2006). A key feature of pollination networks is their nested design. This means that the core of the network is made up of highly connected generalists (a pollinator that visits many different species of plant), while specialized species interact with a subset of the species that the generalists interact with (a pollinator that visits few species of plant, which are also visited by generalist pollinators) (Anders and Jordi, 2007). As the number of interactions in a network increases, the degree of nestedness increases as well (Jordi *et. al*., 2003). Another feature that is common in pollination networks is modularity. Modularity occurs when certain groups of species within a network are much more highly connected to each other than they are with the rest of the network, with weak interactions connecting different modules (Jens *et. al*., 2007; Yoko and Jens, 2009). Within modules it has been shown that individual species play certain roles. Highly specialized species often only interact with individuals within their own module and are known as 'peripheral species'; more generalized species can be thought of as 'hubs' within their own module, with interactions between many different species; there are also species which are very generalized which can act as 'connectors' between their own module and other modules (Jens *et. al*., 2007). Community-level approach has benefited from a network perspective (Jordano *et. al*., 2003; Va´zquez and Aizen 2004). Mutualistic networks can be described by two properties: First, they are very heterogeneous; i.e. the bulk of species have a few interactions, but a few species are much more connected than expected by chance (Jordano *et. al*., 2003). Second, mutualistic networks are highly nested, that is, specialists interact with proper subsets of the species interacting with generalists (Bascompte *et. al*., 2003).

CONCLUSION

The effects of the present biodiversity crisis have been largely focused on the loss of species. However, a missed component of biodiversity loss that often accompanies or even precedes species disappearance is the extinction of ecological interactions. The consequence of species interactions loss for biodiversity is just an emerging field. Anthropogenic impacts are the most evident causes of biodiversity loss, but other causes can also be at work. Since pollinator scarcity is the main factor responsible for inadequate pollination, solutions to this lie in increasing the number of pollinators. This can be done by conserving populations of natural insect pollinators by promoting integrated pest management and by enhancing use of botanical extracts as pesticides, therefore, the chemical pesticides use should be applicable if recommended to use only. In addition, the use of chemical fertilizer has also need attention. There is a need to formulate policies that include pollination as an integrated input to agricultural production technologies.

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