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Invasive Exotic Plant-Pollinator Interactions

B.C. Anu and Ramanuj Vishwakarma

Abstract

Pollination is an imperative biological process, and the exotic plant species have a significant effect on the interaction of plant with pollinators. The exotic plant communities have the ability to cause both direct and indirect impacts on pollinators. The impact of non-native exotic plants on native pollinators can occur at a varying range of scales: starting from the flower visitors who visit flowers individually, to populations and community-level interactions (insect-flower interaction networks). As it is impractical to study every invasive plant in every ecological context, understanding appropriate individual-level trait predicting direct interactions between invasive exotic plants and native pollinators is needed.

Keywords: community-level interactions, ecological context, exotic plant, flower visitors, invasive, non-native

1. Introduction

Pollination that is dependent on an insect is essential in many plants for seed and fruit production, and flowers offer the nectar and pollen that are required for the development of many insects. A lot of attention is gained from ecologists on plant-pollinator interactions, which been perceived as robust architectural property networks [1]. The networks between plant and pollinators are highly enclosed, and they consist of generalist species that interact with both generalist and specialist species; there is a connection between this generalist and specialist species structure [2]. It has been claimed that this kind of structure is often environmentally stable along with low sensitivity to sampling effort [3]. The proof of stability in the plant-pollinator network is fright in front of global change as it is mostly based on the species removal models [4] and destruction of habitats [5]. There is a frail and unsymmetrical interaction between plants and pollinators, that is, it is the pollinator species on which plant species depend and that pollinator species weakly depend on reciprocal plants and *vice versa* [6].

Biological invasions can definitely serve as natural community experiments [7]. We can test whether there are disrupting effects of a new species to a community upon insertion on the network of plant and pollinator by comparing communities that are invaded naturally and communities that are uninvaded or by investigating the invasion activities. It has been suggested that there is an efficient use of pollinators that are native, upon the establishment of many invader plants that are generalist and entomophilous [8]. Moreover, the main harmful impact of non-native plant species on native plant pollinators can be demonstrated through plant-pollinator interaction analysis [9].

There may be a negative effect of invasive alien plant species on plant-pollinator networks such as shading because globally the shrubs compose 23% of invasive plant species [10]. There may be an adverse effect of exotic invasive plants on the ecosystems that they invade, leading to a loss in biodiversity and changes in the functioning of the ecosystem [11]. But, so far this theory has not been supported universally by the studies; the results are dependent on the surroundings and vary on the basis of the traits of the invaded community and the invaders [12].

Study has shown the negative impact on the reproduction of native species by the invasive species, especially when the latter is more abundant [13]. The direct effect of non-native invader plants on native pollinators and their role in the invasion of plants has been focused on in some studies. These direct interactions may affect the fitness of both pollinators and the invasive plant species. Keeping in view the above facts, we have tried to wrap information on the impacts of exotic plant species on native pollinators.

2. Role of pollinators in promoting non-native plant invasion

We know very little about the pollination activities of invasive pollinators in their native range that are present worldwide; whether the pollinator species or the similar groups same as pollinators exist in new areas; in the new areas, flowers are visited by which pollinator species; whether there are limited pollinators; how much the pollinator service quality is important; or whether through other means of reproduction they are successful. There has been a study of a few species in the ecology of the pollination in both exotic invasive and native ranges; for example, in Spain, *Hedysarum coronarium* is native on the mainland and to Balearic islands where it has been introduced [14]; *Rhododendron ponticum* is native to Spain, and it is introduced in Ireland where it is highly invasive [15]; and *Nicotiana glauca* is native to South America, and it is globally introduced [16]. In all the cases of the invasive non-native plant species, the native pollinators that are resident and belong to the same functional group as the non-native plants in their native ranges do the successful pollination. The pollination of *H. coronarium* in native, as well as non-native areas, is done by the same species (Hymenoptera and Coleoptera), particularly, the honeybee *Apis mellifera* [14]; in Spain, large bees *Xylocopa violacea* and *Bombus* spp. pollinate *Rhododendron ponticum* and in Ireland, *R. ponticum* is pollinated by *Bombus* spp. [15]; and hummingbirds pollinate *N. glauca* in the native range; and in the invasive range, specialized sunbirds pollinate *N. glauca* [16].

Nonetheless, knowledge of the ecology of pollination in most species is far more complete in non-native and native regions, as well as for those receiving a great amount of scientific and public attention. For example, in the northern temperate regions, pollination in a notorious invader *Impatiens glandulifera* is done by a variety of bee species in its non-native invasive range [17], but in native India, Pakistan, and Nepal, little is known about its pollinators except for food it is visited by *Bombus* spp. [4]. The role of pollinators in promoting invasion in non-native ranges is poorly studied. Theoretically, the establishment and spread of invasive plants are dependent on the replacement of lost mutualists (including pollinators) from a plant's native range with new mutualist partners in the non-native range [8]. It follows that the self-compatible invasive plant species that can reproduce through asexual propagation and self-pollination plants would be better invaders, as they are less likely to experience a limitation in pollination (i.e., reduction in quantity and quality of pollination service in the new habitat) [18].

Although, through the studies on the invasive plant, characters have revealed that many invasive species are pollinated by biotic agents [19]; but in the case of certain species, self-pollination in high levels can enhance successful reproduction as well as invasion, in a similar way visit by generalist pollinators can also boost the success in reproduction as well as invasion [20]. The pollination service quality is not guaranteed even if appropriate pollinators are present. Pollinators may lack the required phenology or behavior to provide high-quality pollination, resulting in heterospecific or low-quality pollen transfer. In order to become successful invaders, non-native plants, which are pollinated by insects, have several options available. Their pollinators can be introduced alongside them, either simultaneously or later. For example, *Ficus* spp. became invasive in both Florida and New Zealand after the introduction of fig wasps that are host-specific, and viable seed production began [8]. In other cases, pollination may get easier by introducing generalist pollinators. There can be reasons for it, such as either due to the nonexistence of suitable species of pollinator that are native or may be due to the presence of a preexisting adaptation promoting the interaction between plant and pollinator. For example, the introduction of European honeybee (*A. mellifera*) and bumblebee (*Bombus* spp.) to New Zealand introduced European plants as they are frequent pollinators of European plants, for example, *Trifolium pratense* and *Echium vulgare* [21]. Similarly, in North America, introduced *A. mellifera* is a major pollinator of invasive European/Eurasian species *Lythrum salicaria*, *Cirsium vulgare*, and *Rosa multiflora* [22], and in India, *A. mellifera* was primarily introduced as major honey-producing species that becomes later a major pollinator of a number of oilseed crops viz., *Brassica* spp. [23] and *Helianthus annuus* [24], a second important pollinator of *Mangifera indica* [25] and also observed as least visitors of *Capsicum annuum* in the absence of other important floras [26]. Given the broad range of agricultural areas in which *A. mellifera* and *Bombus* spp. are introduced for crop pollination worldwide, they have the ability to promote invasion by a wide range of plant species with which they have coevolved. Pollinators already present in the new habitat can form novel interactions with non-native plants, co-opting them into pollination roles [19]. In many cases, pollinators are frequently native generalists of the same functional group or species as same as the pollinators in the native range of plants, such as *H. coronarium*, *Rhododendron ponticum*, and *N. glauca*.

In other instances, the non-native pollinators that are generalists have coevolved with the close relatives of the non-native plants rather than the non-native plant itself. Again, some good examples of this are the generalist bees that are introduced for crop pollination, such as *Apis* and *Bombus* spp. In Australia, introduced bees (*A. mellifera* and *Bombus terrestris*) pollinate *Lupinus arboreus* [27], and it does not occur in the native range of the species but to the species that are functionally similar to the native pollinators of *L. arboreus* and in Europe, they pollinate native *Lupinus* species. There are also cases where pollination by resident species is done for the relatively specialized pollination system of the plants; for example, in South Africa, *Lilium formosanum*, a non-native invasive species, are pollinated by a widespread hawk moth pollinator [28].

Some of the plant species that are pollinated biotically have become invasive without the need to reproduce sexually and have spread by vegetative means across their invasive range. For example, in parts of its European range, the invasive *Fallopia japonica* entirely relies on the clonal spread, while it reproduces sexually in North America [29]. This phenomenon has been caused by a lack of sexual partners (male individuals that are fertile) rather than a lack of pollinators in this case. *Oxalis pescaprae* is another invasive species that spreads via clonal bulb development in parts of its Mediterranean Basin range (**Figure 1**) [30].

Figure 1.
Interaction of non-native invasive plants with native plants and pollinators [15].

3. Impact of invasive plants on flower visitors

Although interactions with native pollinators may benefit invasive plants, the effect of invasive plants on native flower visitors is thought to be the opposite [31]. This may be because non-native invasive plants take up space that would otherwise be used by native plants, which are thought to be more likely to provide a suitable resource. Invasive plants can also alter the behavior of pollinators that are highly competitive, resulting in indirect effects that can be added on some taxa of pollinators or flower visitors. Despite the fact that quantifying the effects of invasive plants on native arthropods is more complicated than quantifying the effects of native plants [32], due to their mobility, size, and sometimes taxonomic limitations and on the effects of invasive non-native plants on non-pollinating taxa on which several studies have been conducted [31].

There is a lack of knowledge about how arthropod habitat and dietary requirements are affected by invasive plants in general, not just for insects that visit flowers [31]. Most studies on the impacts of an invasive plant on native flower visitors have focused on the species diversity, abundance, and community composition of taxa in non-native plant invaded sites; very little has been explored on the impacts at the individual level or population level. Conflicting conclusions can be seen from the studies that looked into the impact of invasive plants on pollinator abundance. For example, in the case of non-native plants, some authors have found that the invasive plants increase the abundance of certain species, such as generalist butterflies [33] and bees [34], while others have found that invasive plants reduce the abundance of butterflies [35], bees [36], and entire populations of pollinator [37].

Some research by Moron et al. (2009) and Bartomeus et al. (2010), on the other hand, has found no effect on pollinator abundance. Despite the fact that the impact of invasive plants on pollinator species richness and diversity seems to be more consistently negative [37], several studies have found little improvement in species richness after invasion [38]. Invasive plants have been found to influence not only the number of species but also the composition of populations in terms of the taxa present and the presence of a relative abundance of individuals in each taxon, according to several studies. *Vincetoxicum rossicum*, an invasive vine, in general,

supported a low number of arthropods, with some feeding guilds completely absent and with the presence of very few pollinators [32]. Given the potential of invasive plants to affect the relative abundance of different taxa, and thus the composition and diversity of pollinator species, several recent studies have attempted to characterize these changes by analyzing whether invasive plants cause functional changes in ecosystems.

Examining the flower-visitor interaction network structure in invaded environments has become the most common method of characterizing changes in the interactions between plant and pollinator. Though non-native plants have become well integrated into interaction networks [39, 40], network structure metrics are sometimes unaffected [41]. Invasive species, on the other hand, can dramatically alter the structure of interaction networks, either by changing the evenness of the interaction and density of linkage (the number of weighted links per species) [42] or within the network by forming larger, more linked modules [43]. The extent of effects on the network structure is likely to be influenced by the relative abundance of invasive species in the network [44]. Given the extent of effects on network structure, the ambiguity surrounding the functional consequences of network structural properties, as well as the ability to rewire networks in the presence of invaders [45]. For native animals, invasive plants may provide an alternative food source, but only if native animals can get access (i.e., depending on the visitors and flowers of the invasive species trait complementarity) [22] and only if the food is valuable that too nutritionally and does not harm the health and fitness of those who eat it.

4. Methods to quantify impacts on native pollinators

The effects of invasive plants on native flower visitors have been studied using a variety of methods. To simulate invasion and examine ecological consequences, cut branches or potted plants have been used in some cases [18]. The majority of studies have been “natural experiments, comparing the effects of invasive plants with varying degrees of separation between areas where they are established and growing naturally to areas where they are not with varying degrees of separation between areas [46, 47]. Both methods have advantages and disadvantages: In the first, the effects of a sudden introduction of a new invasive flowering plant, as well as flower visitor response, can be tracked. Effects on the visitors of the flower, on the other hand, are more likely to be behavioral responses to the invader than responses at the community level.

There have been many approaches to design “natural experiments” in the second case. Within a single location, the preference of flower visitors can be determined by comparing visits to invasive and native flowers that are both present on the same site. Within a site, visitation to both non-native invasive and native flowers could be recorded, and this could be done by comparing the visitation to native flowers by the pollinators in the absence of the invader. The most common use of this method is to investigate the effects on interaction networks through invasion [46]. The majority of studies have compared the abundance/richness of taxa at invaded vs. control sites, or invasive vs. noninvasive (control) plants [7]. Another strategy is to exclude the invader from a site and investigate the impact on the flower visitor population associated with the remaining native plants in that site, or compare it to populations in invaded or uninvaded sites [40].

An alternative method of determining whether flower visitors are affected by an invasive plant because of its invasive status is to compare the role of the plant in invasive ecosystems versus native ecosystems. This method has not been used often,

but it may be useful in assessing impacts because an attractive plant species that dominates interaction networks in its native habitat may have similar effects when it is not native.

Thus, investigating invasive species through biogeographical studies that look at both their native and introduced ranges may provide valuable information about invasion ecology. However, since many of the effects on flower visitors of invasive plants may be due to the abundance of flowers they grow on and thus are highly rewarding, a different approach would be to compare the effects of invasive plants with the effects of highly rewarding native plants. Then, rather than just the effects of a highly rewarding species in a system, we may be able to separate the effects of non-native invasive plants on flower visitors as a whole.

5. Conclusions

Interaction is often formed between invasive plants and native flower visitors, and their invasion is often reliant on these interactions. Despite the widespread belief that invasive plants have a detrimental effect on native flower tourists, there is no evidence to back this up [48]. In view of the challenges of studying so many flower-visiting taxa, it is not surprising that the direct effects on the diet of individual flower visitors, their health, and fitness by the invasive plants are poorly understood. Given the complexity of performing experiments to assess the effects and the wide variety of responses that can be measured, we are only likely to be able to evaluate impacts for a small percentage of the potentially affected species (most likely insect species that are commercially accessible and/or can be manipulated in a laboratory setting). Moreover, since the effects of invasive plants are likely to be specific to plant species and ecological background-specific, our knowledge is likely to be restricted to globally distributed, problematic plant species. However, better predictions of impacts can be made by designing suitable studies [49] and integrating more knowledge of plant and insect species traits (including plant the breeding system, pollination syndrome, nectar chemistry, insect body size, and diet breadth). As a result, more research into invasive plants and the ecology of flower visitors is needed before broad conclusions regarding direct impacts can be drawn.

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Conflict of interest

The authors declare no conflict of interest.

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