

Review Article

Pollution and pollinators: A review

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Abstract

Biodiversity of Pollinators is declining day by day due to diverse environmental issues, posing a serious threat towards ecosystem services. This review aims to observe the pollinators' loss due to pollution, the different types of pollution causing decline of pollinators and alteration of plant-pollinator interactions due to these contaminants. It also maps the precarious role of pollinators in ecological stability and crisis of food security. Recapitulating literature of few decades from 1955-2019, a continuous trend of pollinators' decline was observed. Air, soil, light, noise, pesticides and heavy metal pollutants are basic pollution drivers for decline of pollinators. These pollutants have affected both plants and pollinators fitness and caused a serious decline in many species of pollinators. Almost 40% of moths and butterflies are at risk of extinction. If this rate proceeded for next few decades, will become a threat towards food security and economic instability. Conservation programs should be launched and followed to conserve precious biota on local and the global scale. An international accord must be started for restoration of pollinators' ecosystem globally.

Keywords: Biodiversity; Conservation; Decline; Ecosystem; Food security; Pollutants

Introduction

Diversity of plants is maintained by the basic role of pollinators, which make pollination possible [1]. About ninety percent of flowering plants depend upon pollinators for their pollination [2]. Over a span of 400 million years, plant-pollinator relationships have coevolved [3]. Biodiversity of various plants depend on insects pollinators like bees, wasps, ants, true flies, butterflies, moths, beetles and many others [4]. Insects are very sensitive to minor changes in environment and act as best bio-indicators of pollution [5]. The sole objective of this review is to illustrate mainly pollinators' diversity loss due to pollutants and their effects on pollinating behavior. The basic theme is to study different forms of pollution that impair the abilities of pollinators to pollinate certain

plants. Many drivers are contributing to decline of pollinators on the global scale [6]. According to a study performed by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in 2016, it's concluded that about 40% of insect pollinators including mostly moths and butterflies are at risk of extinction [7]. Pollution is suggested as the key element of pollinators' deterioration after habitat loss, its proportion is almost 25.8% [8]. Different forms of pollution are affecting insects including, pollution due to pesticides (13%), fertilizers (10%), and due to others urban and industrial factors, counts only 3% [9]. Plant reproduction is affected indirectly by night lightening in streets, but effects can be minimized by utilization of different technologies [10]. Pollution has affected the plant-pollinator

relationships, different pollutants lead to contamination of pollens and honey, different metals are also causing killing of honeybees and contaminating pollens, but no effect on nectar [11]. Quality of environment is illustrated by the honeybees due to radioisotopes buildup in honey and pollens [12]. A decline of almost half of insect species has been recorded since, few decades and some are at verge of extinction, food production methods should be changed to save rich diversity, and otherwise these would be at peril of extermination in succeeding few years [8]. This loss is a threat toward food security and a leading cause of economic instability globally [13, 14].

The decline of pollinators; globally

Anthropogenic activities are major concerns regarding biodiversity decline of ecologically important species of insects [15, 16]. Chemical fertilizers, pesticides, and other urban drivers had left a negative impact on invertebrates' biodiversity along with vertebrates [17-19]. In German 76% decline in biomass for flying insect's population was revealed, after a long monitoring analysis of twenty-seven years. [20]. Recently recorded losses of arthropods in "Puerto Rico" rainforests are 98% for foragers of ground and 78% for inhabitants of coverings annual losses counts (2.7 % and 2.2%) from data of thirty-six years [21]. Dipteran loss is more obvious in Britain especially in southern areas [22]. Insects contribute a major portion of species on this earth, if this trend continues it could lead to 6th chief extermination that badly influence ecology [23]. Loss of insects mainly butterflies, wild bees and ground beetles species is far more than the birds or plants for same period of study and it contributes a lot to the disturbance of ecosystem functions and natural food chains [23]. Pollution is regarded as the 2nd major cause of pollinator's loss, pollution may cause due to land pollution, and chemicals released from factories, industries and other sites of mining, among them industrial pollution

participates (3%), pollution due to pesticides counts for (13%) and role of fertilizers is 10% [8]. In comparison, herbicides are least toxic as compared to fungicides and insecticides [24, 25]. Moths have greatly decline in the United Kingdom due to pesticides [26, 27]. In Italy pollinators have declined due to pesticides [28]. Populations of butterflies along with ladybirds have reduced due to insecticidal use of systemic nature [29]. Honey bees being collapsed by the toxic effects of insecticides [30]. Plant pollinating insects that feed on nectar (butterflies, bees, parasitic wasps and hoverflies) are influenced by the presence of these toxic elements because of their translocation to pollens, nectar and main tissues of plants [31]. Moths' larvae are badly influenced by pollution created by metals has been seen from report studies of Europe [32]. Data obtained from monitoring of 66 butterfly species from North-eastern Spain represented that 15 species increased in number, 5 were stable in number but rest 46 were diminishing from 1994-2014 [33]. In the UK 15 among 17 species of butterflies are threatened due to Neonicotinides [34]. In the United States of America among populations of bumblebees (the great pollinators) it was predicted that among 16 species, 9 are deteriorating and 5 are threatened while only one was in increasing abundance [35].

In agroecosystems, major role in pollination is played by the wild bees that contribute nearly 20% of total pollination [36]. They required a narrow range of food and limited habitats [37]. A decline of 23% in bees' population has recorded from the Great Plains [38]. Due to loss of bees only 24% of pollinators and plants interactions are conserved while the rest have been changed and this alteration is caused by regular decline of bees' population [39]. In 1947, six million colonies of honeybees were recorded, but now this number has been declined with loss of more than half and chronicled a yearly loss of 0.9 % [40]. This rapid loss is attributed collectively to use of

pesticides, fertilizers, insecticides, pathogens and other stressors [14, 41, 42]. Annual based losses of pollinators that are being recorded for different countries had shown a loss of 29% in South Africa, for china it was 3-13%, [43] for America 40% [44] and 30% for Europe [45].

Pollution drivers of decline

1. Air pollution

Air pollution is a suggested cause for decline of Lepidopteran species, due to observed low richness near industrialized areas in Europe, a hypothesis was suggested that air-pollutants in polluted leaves cause extinction of sap-feeding butterflies [46]. Pollutants (such as ozone) are effecting the floral hydrocarbons that are essential to attract the pollinators these when released in air, are disrupted by other air pollutants, in turn they are effecting the foraging efficiency and pollination by pollinators [47]. The persistence levels of scent trails have been declined from kilometers to few meters in recent years as compared to past times, due to low concentrations of volatiles, pollinators have to travel long distances and spend more time in food searching that effects fitness of pollinators along with plants in patchy and polluted landscape [47]. Indirect effects of traffic induced air pollutants on pollinators, validate that these become troublesome for resource allocations dependent on odour recognition in them [48, 49]. Memory, olfaction, cognition of honeybees is reduced by pollutants that enter in air via diesel consumption [49]. Diesel exhausts release such components that alter the bees' behavior towards recognition of host plants, can degrade floral signals and lead to reduced rates of pollination by them [47].

2. Light pollution

An under-appreciated group of nocturnal pollinators are moths (Lepidopteron) a decline in their populations has been recorded in the European countries due to artificial lightening [50]. Artificial lights at night seriously disturb moths, and their role (pollination) in ecosystem, that introduce fluctuations in moths' interactions to other

species, reproduction and morphology therefore, it is indispensable to minimize impacts of lightening on nocturnal moths' activity [50]. Artificial light at night (ALAN) caused a decline of 62% in visitation by nocturnal pollinators that led toward 13% decline in fruit dispersal of thistle in Alpine meadow even in presence of day pollinators [51]. Light pollution plays 20% role in affecting moth' abundance evident from the Ireland and the UK [52]. Globally ALAN has proved a danger for fireflies' conservation that are also good pollinators [53]. Sensitivity of compound eyes are affected by artificial lights, indirect effects have been seen on visual capacity of moths. As visual cues are very important for them to locate flowers, but in presence of sodium lights of low pressure this ability is impaired [54]. Ocelli are also sensitive to changes in intensity of light [55] which effect light initiation at night in moths [56]. Predation rate on moths is also increased due to less defensive behavior of moths in presence of lights and they become susceptible to predators [57, 58]. Reproductive behavior is also effected by lightings, it effects oviposition by female moths they tend to lay eggs in great density near lights [59]. Due to high density, competition for same resources is enhanced [60, 61]. Light pollution effects moths which in turn effect plants diversity, role of moths in agro-ecosystems, in conserving plants diversity and in food web is crucial and pursues consideration for their maintenance [50].

3. Soil pollution

Many factors are causing a decline of important insects pollinators like use of pesticides, loss of habitats, and different fertilizers [62]. Soil pollution due to nitrogen addition by use of organic and inorganic fertilizers, leads to degradation of habitat quality, however, the available data on impacts of plants and pollinator interactions due to elevated levels of nitrogen is very limited [6]. When nitrogen becomes freely accessible which is usually a limiting factor, taller plants grow fastly

while, shorter and slow growing species suffer a lot due to lack of light [63, 64]. Plants get influenced by polluted soil in several ways, like changes in microbes and increased number of pathogens and pest attacks [65]. Soil nitrogen affects several features related to pollinators and floral traits like morphology, phenology, production of pollens/nectar and overall quality is extremely influenced [66]. It has been demonstrated by lab experiments, visit duration on jewelweed by *Bombus* reduced by addition of nickel to nectar [67]. Some other metals like selenium may not directly affect pollinator's response towards flowers but can affect fitness of bees, negatively affect pollinator and plants interactions, it's shown that the inorganic selenium is more toxic for honeybees than organic forms leading to high rates of mortality and negative effects on growth [68].

3.1 Pesticides and heavy metals

Excessive use of pesticides and addition of heavy metals to environment has sternly affected the food searching capabilities of bees as well as their ecological niche has disturbed [69]. Neonicotinoids has badly influenced several activities of bees like memory loss, impaired olfaction [70], reduction of waggle dance [71] and general gestures [72]. Foraging behavior is severely disrupted by the effects of pesticides in bees [73]. Loss of bees' pollinators due to practiced pesticides in agriculture is quite obvious in European countries [74, 13]. Bumblebees are more severely affected by pollution than butterflies according to a comparative study [75].

Heavy metals impose an impact upon plants as well as on behavior of pollinators by affecting reproduction in plants and also bees' foraging [76, 77]. Metals provide a defense in plants towards robbing of nectar but augments the rate of visitation by pollinators however, these pollinators spend least time for foraging and receive less nectar contaminated by heavy metals (Nickel, Zinc, Lead, Copper) as compared to control group hence, a negative impact on foraging was observed but plant

reproductive fitness boosted by increased visitation rate by bumblebees [78]. These results highly supports the "Elemental Defense Hypothesis" because nectar contaminated by metals increased fitness of female reproduction in *Hosta* plants (*Hosta ensata*) [79].

Use of neurotoxic compounds in pesticides directly affect nervous system of pollinators hence, overstimulation leads to paralysis and eventually death, mechanisms of action are not known, developmental problems and larval mortality is commonly seen in honeybees [80-82]. Chronic toxicity has been seen in adult honey bees due to fungicides [83]. The effects of Flupyradifurone (FPF) seen on honeybees predicted that its effect is more upon workers bees that perform foraging activities and effect was more dominant in summer rather in spring season [84].

4. Noise pollution in urban areas

Noise pollution in urban areas are important drivers for reduced activity of pollinators as its seen in a study from Argentina that visitation of House sparrow (*Passer domesticus*) reduced at weekends in response to high pedestrian movements and heavy traffic noises [85]. Effects of elevated levels of noise, being observed in humming birds has shown that rates of pollination are affected in different ways, an indirect negative effect has been observed on establishment of seedlings of "*Passiflora edulis*" due to altered composition of preying animals however, indirect positive effect has been seen on pollination by humming birds [86-88].

Pollinators and food security issues

Many fruits, nuts and herbal crops are pollinated by honeybees almost 87 major food crops are pollinated by insects [89]. Worth for pollinators estimated for one year (2005) is (€153 billion) hence, their economic standpoint is very high. It was also estimated that the crops that depend on pollinators are of much greater worth than others like tubers and roots [90]. It's assessed that (40%) of nutrient supply to humans is given by these crops including

important vitamins, lipids and other micronutrients [91]. Provision of food to wildlife including birds, mammals and herbivores that depend on these plants will be perished due to their non-existence as a result of pollinators' loss [92]. These pollinators have a potential to enhance the diversity of wild species of plants on genetic basis [93]. Quality of fruits, shelf-life as well as marketable values are improved by pollinators [94]. Historic loss of pollinators is challenging food security globally. Since, almost (35%) of food production relies on animal pollinators, that food is a major source of micronutrients for humans, not only these crops but also ornamental plants, fodder, biofuels and other important crops are dependent on pollinators. Hence, food security is threatened by this loss both locally and globally [92].

Results and discussion

The number of pollinators is deteriorating indisputably, generating a disquieting condition, essential steps should be taken for their conservation and to protect their status. As pollution is a factor contributing to diversity loss, it's declared as 2nd major cause after territory destruction for pollinators. The main focus of this review is upon different pollution drivers that causing the decline of pollinators globally, how pollinators are affected by air, light, noise and soil pollution including impacts of pesticides and heavy metals. Further investigation is needed to assess the impacts of different environmental pollutants upon plants-pollinators interactions. Many air-pollutants are influencing bees' pollination and much work is needed to describe impacts on bees' physiology. Heavy metals, elements from petrol and diesel exhaust, night street lighting and excessive use of pesticides mutually exerting pressure on the existence of pollinators directly or indirectly. It has been witnessed that many environmental pollutants are affecting pollinators' ability to pollinate commercially important crops. This issue is becoming a threat to the

biodiversity loss of pollinators as well as plants biota. Conservation programs should bring in work to save rich diversity of and to mitigate impacts on ecology and economy globally as well as locally.

Conclusion and recommendations

Pollinators are affected by pollution adversely and become a second major driver for insects decline, globally. Plant-pollinator interactions are widely effected by certain air and soil pollutants. Impact of Light pollution on nocturnal pollinators is attention-seeking issue and much research work is needed to discover its impacts on overall pollination. Use of fertilizers and pesticides should be carried judiciously on the Integrated Pest Management (IPM) basis to save important pollinators. Low rates of pollination lead not only to biodiversity decline but also economic and ecological aspects are important to discuss. Protection of such precious creatures by the implementation of environmental laws regarding conservation, to mitigate pollution and its effects on pollination is an issue that requires strict Actions. Further research is needed to find impacts of light pollution on moths because these are important for the maintenance of ecosystem services. Detrimental effects of nitrogen deposition in soil, on physiology of pollinators should be researched further. Overall effects of pollution on pollinators should be minimized by the application of certain rules regarding insects' conservation. Hereby, recommended the use of such street lights that have insignificant effect on nocturnal pollinators, use of renewable fuel and clean energy production methods should be practiced to minimize impacts of air pollution on pollinators. Chemicals used in gardens should be minimized using IPM and organic farming should be introduced. An international accord for the restoration of pollinators' ecosystem should be commenced to lessen the impacts of this decline.

Authors' contributions

Critically examined the data and inputs from all the authors: MF Malik, H Razzaq, T Amjad & A Anjum, Reviewed the manuscript: T Amjad, F Fatima & N Fatima, Wrote the manuscript: J Riaz.

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