Chapter

Causes and Reasons of Insect Decline and the Way Forward

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Abstract

There are lot of reasons and causes of insect decline. The main causes of insect decline is attributed to habitat destruction, land use changes, deforestation, intensive agriculture, urbanization, pollution, climate change, introduction of invasive insect species, application of pesticides, mass trapping of insects using pheromones and light traps, pathological problems on various insects, and introduction of exotic honey bees in new areas that compete with the native bees for resource portioning and other management techniques for pest management, and even not leaving any pest residue for predators and parasitoids for their survival. The use of chemical insecticides against target or non-target organisms is major cause for insect decline. The diseases and decline of the important pollinators is still a mistry for colony collapse disorder. To overcome the cause of insect decline, various conservation techniques to be adopted and augmentation of artificial nesting and feeding structures, use of green pesticides, maintaining the proper pest defender ratio (P:D), policies and reaching to political audience at global level and other factors already discussed in the chapter may be helpful for mitigating the insect decline and especially for the pollinators, a key insect for life.

Keywords: insect decline, pollinators, causes, effect, mitigation measures

1. Introduction

Globally, scientific studies have reported a large and significant decline in insect populations since decades [1]. The policies and public concerns for insect decline is scarce and highly ignored since the dawn of civilization. Garden columnist George [2] warned the world regarding the decline of insect numbers. Insect decline is a serious threat because their abundance, numbers, diversity and the extinction of whole species. Decline in population does not mean only reduction in the insect numbers but also means the restricted graphical distribution which leads to the first step of extinction [3]. The causes of insect decline, and pattern are not uniform and vary with biotic, abiotic, and anthropogenic factors of the region [4]. Globally scientists are concerned for biodiversity loss in terrestrial and aquatic vertebrate [5, 6] and are more concerned to invertebrates. Although the number of insect fauna is huge, they have always have always been ignored by ecologists and conservationists.

There are about 5.5 million species of insects all over the World, out of which 90% species are still not been identified and their function in ecology is unknown. The number of insects in Germany has declined up to 75% in just 4 year [7] and also declined in Netherlands as well [8].

A meta-analysis data concerned to terrestrial insects published in Journal *Science* in 2020 reported a global insect population decline by 9% per decade [9, 10] in contrast to fresh water insects whose population is enhancing very fast at 11% per decade [11, 12]. Terrestrial insects are more vulnerable to diverse threats [1] and some of the most affected insect groups namely bees, butterflies, moths, beetles, dragon flies and damselflies [13]. Anecdotal and accurate evidence of population trend variability in particular locations has been offered with high [1] apparent abundance of insects during the twentieth century, as confirmed by recollection of windscreen phenomenon [14]. The possible causes of insect decline is due to [1] habitat destruction, intensive agriculture, extensive use of synthetic pesticides, urbanization, industrialization, species introduction, shifting agriculture, genetic engineering and climate change [1]. According to one report by World Economic Forum 23% of Earth's habitat would disappear by 2100 century [15] and conservation of habitat ensures the long-term survival of life on the planet; and its loss is identified as the main threat to 85% of species listed in the IUCN Red List. Research says that not all insect orders have been affected at same rate; and some orders need to be researched and revaluated because figures from earlier periods are often not available or standard scientific techniques have not been used to quantify their decline [16, 17]. The notion of insect decline is widespread globally and various [1] insect conservation measures have been launched to the judicious use of synthetic pesticides and other measure for habitat protection [18]. German government initiated an Action Programme for insect protection in 2018 and the British entomologists and ecologists wrote an open letter to have a focused research to know the reasons and causes of insect decline [19].

1.1 Background of insect decline

From the previous two centuries, insect decline has started rapidly [10]. The old recorded decline of Rocky Mountain Locust during 1902 [20] in USA and recently the scientists from the University of Helsinki warned humanity about worldwide insect decline with unpredictable consequences [21]. Civil society and policymakers have an important role for the future and collective well-being of insects and most of the insects are responsible for pollination, predation and parasitisation and waste material degradation in different ecosytems. Mitigating the impact of climate change, establishing buffer zones with high-quality and manageable portions of fertile land for protection, and changing agricultural practices to foster species coexistence, besides leaving a pest residue are all things that need to be done [22].

Ten trillion locust swarms were observed during 1975, and rapidly declined afterword's but the causes of such decline is not explored [23]. This species was declared extinct in 2014 due to its continued decline. However, the fossil records concerning to insect decline revealed that insect stretched back hundreds of millions of years with the discovery of new species and their extinctions [24]. Further, it is also observed that mass insect extinction occasionally occurred by natural phemenon like volcanic activity and meteorite impacts [25]. The insect decline was highest during Permian–Triassic extinction event followed by second highest mass extinction during Cretaceous-Paleogene era [26]. However, the insect diversity and abundance has resumed rhythm after first extinction giving birth to new species at higher rates, however still it will take millions of years to restore the extinct ones [6]. The latest human caused [1] Holocene extinction of species is growing since

20th century, and much of the extinction reports were not from arthropods, with 95% decline in anthropogenic habitats like grasslands [27]. In the case of vertebrates, the Zoological Society of London (ZSL) published a research-based opinion in 2012 that insect species are decreasing globally, with direct and indirect effects on pollination, ecosystem balance, ecosystem services, livestock, and overall food production, and may decline in the near future [28]. It is estimated that 20% of all invertebrates are in grave danger of extinction as a result of Holocene extinction. Generally in Holocene era, the species with least mobility, small size, smallest host ranges and climate sensitive are most vulnerable to extinction [29].

After decades, it has been noted that species extinction is on the decline; however, precise data is unavailable. Several research found a big gap between 1840 and future predictions. However, due to the global concern about species extinction, the German Nature Reserve gained a lot of attention in 2017 [8–30].

Several studies have found that declining insect abundance, biomass, and species richness are all signs of species extinction [31]. The reports revealed a localized decline in species-friendly factors, implying that species showed a region-wide decline but not necessarily in other areas. Moths, bees, beetles, dragonflies, damselflies, and stoneflies were the most studied insects in terms of extinction [4, 32]. All these species are affected directly or indirectly in many ways through changes in environment. Many insect species have adapted to external changes when environmental conditions change in some way; however, the majority of species fail to live in altered environments.

By the year 2019, the reports published by Entomological Society of America highlighted that the available data concerning to extinction of insects is not satisfactory and insufficient to support imminent mass extinction [33]. Extrapolated forecasts may have been stretched, and data ranges about different species have been over-hyped, underestimated, and overestimated, according to society. The decline of some groups (butterflies, bees and beetles) have been documented by European studies, while other regions have recorded an increase in species count, however the definite and clear trend of insect decline from most part of the world is not available. Due to lack of sufficient information and historical measurements about majority of insect species [34]. It is very cumbersome to assess their long-term shift in abundance, diversity, and habitat. For many of the species, an exaggerated and extrapolated data is available without a proper trend to conclude anything about decline. Further the robust data collected from risk areas habituating various species is especially insufficient to assess any trend especially from arctic and tropical regions of world, for example southern hemisphere [35].

1.2 Causes of insect decline

Globally the well-known cause of insect decline is attributed to many factors [36]. The most important among them are habitat destruction due to intensive agricultural practices, urbanization, pesticides use, introduction of new species, climate change and global warming, eutrophication, pollution, genetically engineered plants, UV radiations, ozone depletion and artificial lightening [4] .

In today's agriculture and horticulture crop systems, pesticides and herbicides are used on a large scale, affecting non-target species, insect-plant interactions, soil they live in, and air they breathe.

The excessive applications and quantity of chemical insecticides and herbicides on plants have not adversely influenced the non-target arthropod species but also their host food plants at an alarming rate [37]. Impacts of prevailing climate change and the introduction of exotic species have generated the competition with the indigenous species due to which native species are under pressure, with the

consequences the species are probable to succumb to biotic and abiotic factors. The higher CO_2 levels in any agro-ecosystem enhance the faster vegetative growth in plants producing higher biomass and lesser nutrients due to reduced photosynthesis [38, 39]. Further, the insect species especially Dipteran (flies) and Dictyopteran (cockroaches) populations may increase however, overall projected insect biomass under higher CO_2 levels may decrease ranging from 0.9 to 2.5% per year [40, 41], and insects are losing an average 10–20% of their land every decade, which is horrifying. According to one latest meta-analysis report the intense reductions (up to −80%) in insect abundance and biomass confirmed an observed species richness declines ranging from 20–40% on seasonal basis, especially the decline of dipteran species contributed by consequences of improper functioning of ecosystems [42] due to many factors.

1.2.1 Habitat destruction

Cutting down of trees converting wild land into agriculture, silviculture and other commercial developmental usage can lead to the great decline in the diversity of living organisms all around the world [40, 41] Habitat change is primarily due to human activities and its scope has been expanding over the past centuries because large amount of land has been transformed to provide dwelling, and facilitate transportation and tourism infrastructure, at the expense of natural habitat. Among insect species, order, Coleoptera, Lepidoptera and Hymenoptera are most affected by the habitat destruction [42].

1.2.2 Pollution

Pollution has always been one of the serious threats especially industrial pollution to reduce the insect population and leads to reduction in the viability of insects [37]. Exhaust fumes from cars has increased level of nitrogen dioxide [43], air pollution [44], aquatic pollution, Light pollution [45] are the serious threats to population including insect fauna.Pollution is considered as a major cause for insect decline [42] and environmental pollution Viz., uses of fertilizers and synthetic pesticides in agricultural production, usage of sewage and landfill beaches from urbanized areas, chemicals released from various factories and mining sites. These all cause air pollution accounting to 13% [46]. Toxicity of insecticides are most toxic followed by fungicides and then by herbicide on insect decline. Application of herbicides to any crop land affects more negatively to both terrestrial plants and insect fauna than any other agronomic practices [47]. In rural areas of UK, pesticides found to cause decline in the number of moths and pollinators in Italy [48].The uses of broad- spectrum insecticide destroy ground developing insects [49] While, the use of systemic insecticides cause reduction in the population of lady bird beetles and butterflies [50]. Besides, nicotinamide and fipronil insecticides showed a very negative impact on aquatic insects [51]. Usage of fipronil results in the reduction in the number of dragonflies [52]. Nicotinamide is considered to be the main cause of reduction of dragon fly population in Japan [53]. Usage of avermectins cause decline in dung beetle population [54].

1.2.3 Land use change

Land usage change is also one of the serious causes for the insect decline. Land use change simply means changing the habitat of many ground dwelling and terrestrial insects, causes their decline and eventually leads to their extinction. Many insects are threatened due to the destruction of various small farms. Small and

traditional farms and converting these to more industrialized farms is very detrimental to insect decline [55] so by converting the natural habitat into augmented concrete structure around bunds and other water fills.

1.2.4 Deforestation

Tropical forests are home to the majority of insects. So by cutting these tropical forests for crops for various purposes is the most serious threat regarding the biodiversity of insects [40]. Cutting down trees on large scale altars rainfall patterns, and insect populations and their developmental activities [45]. Deforestation is directly linked to the decline in the population of insects because when trees are cut the insects dwelling on those trees are ultimately destroyed and considered to be the biggest habitat for living organisms including insects so by cutting the forest causes a serious threat to all the biodiversity including insect faun [42] as forests are considered as stable ecosystem for all living creature.

1.2.5 Agriculture

In the recent years, agricultural infestation has also accelerated [56] which eventually resulted in the change in the composition of insects. The factors for agricultural infestations are responsible for insect decline. Such as artificial drainage causes the reduction in wetland which eventually causes the habitat loss for many aquatic insects [57], removing Woodland trees eliminating the insect food and shelter structures of insects [58, 59] besides using inorganic micro fertilizers results in eutrophication which eventually affect the aquatic insects like may fly [60] beside this extensive use of pesticides in agricultural practices is also very serious pest population that's the reason that there is it ever growing link of literature linking the insect decline with the agricultural intensification. Agricultural intensification eventually results in homogenization of microhabitat and causes changes in the insect communities. Combination of different waterbodies lead to eutrophication sedimentation in water bodies that causes reduction in various predators [57, 60]. Aquatic plants are very important provide refuge for the insects belonging to the order Odonata [61] and reduction in the insect biodiversity is also caused by the loss of streamflow and river trade water bodies.

1.2.6 Urbanization

Urbanization is also considered to be one of the main causes for insect decline. Globally, urbanization is increasing day by day which leads to habitat fragmentation and converting the large habitats into smaller areas and converting the forest into agricultural areas and communities [62]. In tropical West Africa, huge decline in beetle and wasp populations were observed due to urbanization [21, 62]. Globally, agricultural fields has been converted into urbanization areas to meet the demands of urban population for their housing and other needs that leads to insect decline where these insects had been living since decades.

1.2.7 Climate change

Nowadays ecologist and conservationists are working to relate the climatic change with the decline of insects [21]. Climate change has become one of the reasons for the decline of butterfly and wild bees [63]. Insects in tropical regions usually have a very narrow thermal thresholds and very susceptible to temperature fluctuations. Besides, global warming can enhance the population of butterflies,

their geographical distribution and more towards northern areas [64]. There are reports that more than half the world's insect populations are declining due to the global warming [65, 66]. Global warming result in a reduction of populations of some dragonflies, bumblebees and stoneflies which are mainly adapted in cold climates and live in the higher altitude [67]. It has a negative impact on some pollinator and beetles which are located in Mediterranean region., it might increase extinction of many mountain species [68]. The clear evidences of climate change leading to the reduction or decline in the biomass of arthropods in the rainforests of Caribbean Islands [69].

1.2.8 Invasive species

Introduction of non-native or invasive species occur in a particular ecosystem is a threat on the existing population. In areas of human occupation and introduction of invasive plants reduce the insect herbivore loads more than 90%. The reason behind the collapse of honeybee colony in various countries is the introduction of various exotic parasites and pathogens [70] and also leads to the decline of wild bees in North America [71]. The spread of vartmaan destructor mite (*Aethina tumida*) is threat to apiculture industry [72]. There are several reports regarding the impact of invasive plant and animal species on the native insect species.

1.2.9 Pesticides

The use of pesticides is the main causes for the insect decline. Aerial application of pesticides is directly linked with the loss of flying insects and population of pollinators. Imidacloprid and Thiacloprid insecticides have a negative effect on bee navigation but widely used for the protection of crops [73], Nicotinoids are the main cause for the decline of dragonflies in Japan [74] and avermectins for the dung beetles in many countries [75].

1.2.10 Roads, railway networks and air ways

Transport infrastructures such as roads and railways and airways are very important nowadays for the basic necessities for human population [76]. Despite being extremely help for the human civilization but very dangerous for insect biodiversity, fragmentation of land due to the construction of roads, railways which causes habitat loss of many insect species [76] found higher mortality rates at intermediate traffic volume compared to high and low traffic rates. Besides, insect crossing on the roads, collusion of insect with vehicles and death of soil borne insects during road constructions [77].

1.2.11 Effects of insect decline

Insects are integral part of ecosystem functioning. The decline of insect populations has direct impact on ecosystems, animal populations, plants, herbs, shrubs and in end on human begins [78]. The structural and functional base of the ecosystems are made by insects and as per global review, the decline of insect populations if not managed and mitigated would have disastrous and cataclysmal effects on global ecosystem. The parasitoids and predators (birds and mammals) which directly feed or host on insects are affected by insect decline [79]. The decline of bees and beneficial bugs reduce the pollination of diverse plant populations and the biological waste disposal [4]. The reports of zoological survey of London revealed that insect decline corresponds to losses of instrumental values and the species intrinsic values.

1.2.12 Evidence of insect decline

Broadly speaking there are three most important metrics capturing and reporting the insect decline, as an evidence for determination of insect decline globally [80]. The first important component is insect population abundance which determines the numerical total of individuals in any particular ecosystem. The insect abundance is measured differently under different contexts; however, the overall intend refers to number of insect species per meter square of plant, in any assembly, per unit geographical area or sum total of insects present globally. Biomass is second important metrics of insect estimation through their total weight irrespective of insect species into consideration. Biodiversity is the third and important metrics [81] based on broader scale of measurements and gives a metadata about insect species existing globally. Like abundance the term insect biodiversity is used under different contexts and the reduction in biodiversity presents an alarming threat. Those species that have vanished locally and some particular species has gone entirely extinct form earth.

The available literature says that most of the studies concerning global insect decline base their studies on few metrics [82] either abundance or biomass or biodiversity or combination of all three and very few meta-data analysis studies recorded all the three metrics for proper estimation of insect decline. The available data of direct evidence of diversity decline and loss is scattered and inadequate for all the three metrics and it becomes difficult to comprehend the true figures of total insect reduction globally. Therefore, the estimates of insect diversity loss at cosmogonic level are inclined to involve the generalization and extrapolating from existing abundance or/and biomass data; however, the true worldwide extinctions figures are demanding to discern and determine.

David Wagner reviewed the literature and proposed that presently the Holocene extinction contributing the species loss to about 100–1000 times as compared to previous pace. Some authors proposed even faster extinction rate and collaborated with Wagner's opinion that rapid decline in insect abundance would have a serious ecological impact. The global decline of megafauna is related to human activities not to climate change [83].

1.2.13 Relationship between metrics based on historical inferences

Ecologists provided different views of relationships among three important insect ecological metrics [84]. Few hypothesized an independent relationship while others explained dependence of metrics on each other either directly or indirectly. For example, reduction in biomass might not necessarily involve a decrease in abundance or diversity. The reduction of particular species means shrinking of biodiversity and consequently the reduction of insect abundance and finally the species is getting smaller in range of expansion and the area is becoming lesser in richness. In real, abundance and biomass are closely related and both sowing decline depending on various biotic and abiotic factors. Therefore, insect diversity is often, though not related to three metrics. The Rothamsted Research Institute from UK conducted an insect survey using suction traps during 1964 and compiled a most standardized long-term data on insects in the world [14, 85]. Suction tarps were installed effectively positioning upside-down Hoovers running 24/7 sampled the air for all migrating insects. Revaluating the data during 2000–2017, the James Bell in an interview in 2017 announced that insect populations in Scotland has reduced while as figures from England has remained comparatively stabilized. The review from [86] and other reports that "Of the all insect populations with IUCN- documented population trend, 33% are declining and 30–60% of species

per order are in declining ranges. With regards to insect pollinators the populations are declining globally both in abundance and diversity; the loss is contributed by human-caused disturbance of vertebrates and invertebrates as the consequence of Anthropocene defaunation [87].

The reports of higher decline in insect biomass were recorded by Krefeld Entomological using malaise traps at Germany. For this study a total of 63 locations were chosen comprised of 57 from Nordrhein-Westfalen, one each from Rheinland-Pfalz and Brandenburg and 4 other from nearby areas. Studies concluded that there were a seasonal and mid-summer biomass decline of 76% and 82% in flying insects. The decline were contributed by several factors especially change in weather, land use and habitat features. The flying insects especially butterflies, moths and wild bees were major contributors to total decline proportion and based on the results of Krefeld German government have established an Action Programme for the Insect Protection.

The decline in arthropods were reported from Puerto Rico based on the surveys and measurements during 1976 and 2012 [69]. During 36 years of studies, the biomass losses evaluated were 98% and 78% for ground foraging and canopy dwelling arthropods with annual losses of 2.7 and 2.2% respectively. The reasons behind this rate of fast decline were average high temperatures; since the arthropods from tropical areas do not tolerate high temperatures. In tropics rapid cold-hardening, ice-interface desiccation and the daily resetting of critical thermal thresholds affecting mortality and mobility with temperature as the most important factor having high influence on insect physiological processes to determine ecological outcomes and survival under harsh conditions [88].

Estimated declines of 84% in butterflies were observed from Netherland during 1890 to 2017 [66]. Further Swiss Academy of Natural Sciences recorded an estimated decline of about 60% in insect- eating birds urging the authorities for the immediate action to resolve the causes of insect decline. Similarly, in another studies of 2019, published in Biological Conservation showed a decline in insect populations from US and Western Europe. Further, the studies showed an annual loss of 2.7% in biomass; and it was hypothesized that this rate of decline may lead to mass extinction of 40% species over next 45–55 years. Extinction of insects groups like butterflies, moths, bees, dragonflies, beetles, dipteran flies, and Orthopteran (grasshoppers, crickets) and Hemiptera (aphids) are more susceptible for loss in terms of abundance, diversity and total biomass. According to global assessment report (2019) regarding various important metrics of insects in environment, the global trends in insect populations were not clearly determined but rapid decline have been well documented in many hot spot areas [89]. Local declines in insect densities (bees and butterflies) and overall global decline in abundance have been observed. Some rapid decline was contributed by many factors like large scale land use changes, rising temperatures, and reduction in conducive habitats. The reports from a meta-analysis studies published in Science showed an average abundance decline of 9% in terrestrial insects; contrary to this an average 12% increase in freshwater abundance were also reported [9]. Rise in aquatic insect populations have been contributed by many important factors such as the sanitary measures and other rapid actions taken by governments in present climate change era, the freshwater bodies have remained clean and people residing near these natural water bodies have been provided awareness for the preservation, conservation and maintenance of the hygienic environment that overall boasted the aquatic insect population besides reducing the water pollinations. Some other studies at US have also presented similar data from different ecosystems with both decline and increase reports showing that overall insect abundance have changed but no net change in biomass has occurred.

Depending on the specific region, the butterfly populations across a large part of North America are declining (North America), increasing (South East part) or

stable based on area sampled [90]. The reasons for these irregular variations were climate change, especially the emission of greenhouse gases affecting butterflies and moths.

1.3 Insect conservation

The insect decline is a global issue and much of the efforts to retain and restore biodiversity at national or international levels are addressed to US as component of Convention on Biological Diversity [91]. The communications and reports typically describe policies and planning to save further loss of diversity through conservation and restoration of habitats, host plants, and measures to reduce disturbances to protect the particular threatened taxa [92]. For conservation point, the prime importance is given to insect pollinators as being most essential and integral part of crop production and the global efforts to reduce their decline are at high priority especially focusing on conservation of bumble bees [93], honey bees and some other solitary bees. The German Environment Ministry started an action Programme for insect protection which aims at promoting insect habitat in diverse agricultural landscapes by reducing pesticides use, light pollination and pollutants in soil and water. The United Nations initiated a compressive sustainable development goals by drafting a policy making community transition from perceiving insects as enemies and injurious to providers of ecosystem services. Entomological Society of America advising the farmers to maintain plant diversity in their farms by leaving some buffer areas, natural habitats, leaf litter and dead woods for insect proliferation and breeding. Similarly, the Xeres Society US stressed collaborators to promote invertebrate conservation for applied research, and advocacy and to promote public outreach and education. The project aimed at the rehabilitation of natural habitat for endangered species, conservation of insect pollinators, restoration and their protection. Further, the phone apps like iNaturalist for photography and identification of specimens and the programs such as City Nature Challenge, National Moth Week and Monarch Butterfly Conservation were initiated.

1.4 Global decline of insect studies

Awareness about insect significance to environment is of high value [94]. Therefore, the lack of this awareness is contributed to the global decline of studies of entomology and taxonomy. The mention in Entomology Congress in US stated that the studies of entomology are themselves as an endangered species and according to one survey the world has lost nearly all experts. General biology courses in colleges and universities have given less attention to insect science and number of specialists are decreasing. Further, the studies related to decline trends, management, diversity and other metrics estimation involved collecting, killing, trapping and ward off which have some ethical issues for conservationists [15].

1.4.1 Biodiversity loss

Biodiversity loss comprised of devastation, extermination and extinction of insect species worldwide [95]. The disappearance of organisms from different natural reservoirs and ecosystems results in a temporary or irreversible loss of insect biodiversity, depending on whether various disruption factors are reversible (ecological restoration and resilience) or effectively permanent (ecological restoration and resilience) (land loss, erosion, deforestation). Human behaviors of different types beyond reasonable range are causing the most permanent changes in the twenty-first century, and leading to high biodiversity losses. The recent and

the big irreversible global species loss is highly catastrophic and tragic phenomenon compared to regional loss in species composition. The regional and minor species composition changes from stable state have a huge negative impact on food web and food chain [96]. Since decreasing and extinction of one species would adversely impact the entire cycle of food chain.

The disturbances and breaks in food chain ultimately lead to diminishing biodiversity, unstabilization of ecosystem services. Decline in insect biodiversity simultaneously presents an immediate threat to food security [97] and moreover, have a permanent and adverse effects on health and wealth of humans. Since years, the International Environment Organization has led a campaign to avoid biodiversity loss by combining public health and biodiversity conservation into a single health solution that can be used as part of international policy. The UN Convention on Biological Diversity aimed at restoration and conservation of biodiversity (2021) loss and proactive measures; Sustainable Development Goal 15 for "Life on Land" and Sustainable Development Goal 14 for "Life Below Water", and the UN Environment Programme were designed to focus for Making Peace with Nature. All these efforts remained either unimplemented or fail to meet their targets on real grounds.

1.4.2 Holocene extinction

Since centuries human activities are pushing environment beyond the recovery and revival to the ultimate catastrophic events of extinction [21, 98]. According to historical prospective of species extinction, the Holocene extinction is considered as the 6thmajor mass extinction event also referred to as anthropocene extinction. The anthropocene extinction is an ongoing loss of species during the current Holocene epoch with the consequences of various human activities especially started with the onset of technological revolution. The diverse spread of destruction of species from biologically diverse habitats is viewed to be unknown and unrecognized. Most of the extinct insect species were either not known to science or yet undiscovered without knowing their cause of extinction. The present speed of species extinction is calculated to be as fast as 100 to 1000 times higher than naturally occurring previously recorded extinction rates [98]. The species at megafauna disappearance during final phase of last glacial period were known to be highly sensitive to predation died shortly at the beginning of hunting activities by human across the earth especially from African region at an onset of Holocene era of extinction event near Pleistocene–Holocene boundary frequently known as quaternary extinction event [99].

1.4.3 Defaunation

The functional extinction of insect species [99] at global, local and regional level is referred as defaunation from ecological communities; triggered by growth and spread of human populations coupled with the advancement of latest technologies; ultimately leading to an unlimited and unbearable exploitation of the ecosystem in which diverse insect species are living. The diminishing and dwindling of the invertebrate species from ecological communities result into the empty forests resulting into species disappearance and reduced abundance. The estimates of more than 50% of all wild life species were lost due to defaunation in last 40 years of Holocene era [100]. The surprising example is from year 2016 contributed by 68% species defaunation in terms of disappearance and reduced abundance compared to even higher species loss of 70% from South America [101]. Regarding this fast defaunation in current era the global gathering of 15000 scientists during 2017 called for

a second warning to humanity for development and implementation of stringent policies to mitigate the Defaunation and exploitation of the natural reservoirs to ensure the safeguarding of remained threatened species.

The endangered insect species are designated to be facing a high threat of extinction viewed by Zoological survey of India (ZSI) in the natural ecosystems. Therefore in 2017 the US International Union for Conservation of Nature (IUCN) sort out a total of 343 endangered insect species comprised of total 5.7% as endangered. Further, the IUCN also highlighted 21 more subspecies as endangered for extinction; however no subpopulations were evaluated by IUCN. For IUCN to consider a species as endangered must fulfill some prerequisites to classify the taxa facing a very high risk of extinction in near future. The critically high endangered species are known to be nearly 538; however, 1702 species (28% of total evaluated) were considered as data deficient with minimum available information to full assessment and for determining their conservation status [102]. However, IUCN noted them as with the same degree of attention as threatened taxa till their status can be assessed.

1.5 Mitigation of insect decline

To maintain the ecological balance of every existing ecosystem for survival is essential. Every creature from microscopic to macroscopic in structure has its own importance and credibility to maintain the existence of the living world. All terrestrial insects provide resources for higher trophic levels, especially for many vertebrates [103]. Natural pest regulation relies on insect presence and their trophic interactions [104]. The local extinction of plants relying on pollinators is related to diminishing of pollinators [105]. The annual value of pollination for agriculture plants is estimated to be 200–600 billion US$ [106] To maintain proper functionality and to mitigate the adverse effects of natural calamities of the environment. Diverse species of insects are under natural as well anthropogenic risks which acts as the main drivers to decline the insect population. Literature survey revealed that the insect population is declining and at an alarming pace at the present scenario. Therefore, research work in this field is not considered important by the entomologists but needs to provide a very special attention. Some of the basic and important features are presented that plays an important role to mitigate the population decline of insects.

1.5.1 Conservation of high quality habitat

High-quality habitat protection and fortification must be given first significance. Various rules and regulations have been framed by various national as well as international organization to safeguard and protect the valuable habitats of insects. Laws framed to protect habitats and other natural surroundings to prevent any kind of destruction or devastation at the European Union (EU) Level, and must be stringently executed in all the member states without any latency. Even though to safeguard diverse species and different ecosystems by the enactment of the Natura 2000 network (N2000), and 18% surface of land is covered by European Union, it is the Habitats Decree (directive) that emphases on susceptible species. Though, many of the targeted species enumerated on the annexes of the Habitats Decree Directive characterize peripheral or even relict populations, and thus the EU often does not cover the primary of their global circulation range [107]. Moreover, Birds and plants were primarily targeted in the Habitats Directive but now there is urge that invertebrates are be included [108]. To meet the demands of new species or to achieve conservation goals, more focus should be given to develop or reinstated high

quality habitats in the farming environment, as the existing environment, as per the Habitats directive, would not be able to assure the survival of species of insects [109]. So a new suggestion is presented that public interest must have precedence over individual proprietorship rights.

1.6 Increasing landscape permeability

"A healthy environment is a key to a healthy living organism", means that if a living creature is nurtured in a healthy environment, that depicts the growth of an individuals with enhanced capability traits. Healthy environment functional networks fosters/helps to long survival of many species [110]. A conclusion is drawn that special economic packages must be supplied to those organizations or agronomists who can employ ecofriendly practices. To increase landscape permeability acts an important factor to mitigate the population decline of insects, so special methods and techniques must be encouraged by policy makers as well as government organizations.

Landscape permeability refers as "that area of habitat of an individual which provides free passage without any obstacle to fulfill survival requirements "Land connectivity can be increased by extending field margins as well as roadside extensions, which in turn increase more area for flowering plants that ultimately leads to insect friendly conditions and thus helps in mitigating insect decline [111]. Beetle movement to adjacent areas is fortified by grassy fields or grassy strips [112]. While, barren lands acts a favorable and healthy environment for bumble bees and butterflies in Finland [113]. Such kinds of existing strategies has been proved economical but also easy to implement and thus easy to understand the insect decline.

1.6.1 Safeguarding habitat quality

Chemical fertilizers and their other insolvable constituents are considered one of the ultimate threats to the population of different species of insects. Intensive farming is excessively dependent upon the chemical fertilizers to yield better output from the crops. The applications of these fertilizers would be reduced to an acceptable level by using alternative organic fertilizers. On the basis of various surveying methods, a large number of food chains and webs are disturbed or completely damaged by the excessive use of these toxic chemicals. The negative impacts have developed so many detrimental impacts and needs to be reduced both in agricultural and urban areas. Neonicotinoids, a kind of pesticides, has reduced bees' population to large extent [114]. Thus there must be special and regular conferences to make awareness among the masses regarding the damaging and toxicant effects of these products of the fertilizers. There are many existing alternative methods to adopt and to implement in place of chemical fertilizers and thus helps to mitigate the declining population of insects to large extent. Organic farming plays an imperative role to sustain biodiversity and enhance insect population with a balanced manner [111, 115, 116]. However, there is still requirement to improve this research further to improve yields by use of organic farming [117].

1.6.2 Mitigate soap run-off from washing

Soap consists of long chain fatty acids which are harmful and detrimental to insects. Soaps are used to wash motorbikes, cars, buildings or washing clothes accompanied by harmful pollutants such as heavy metals, ammonia etc. that are redirected into different water bodies [118]. There are diverse types of aquatic insects heavy affected by such chemicals i.e. they inhibit their metabolic system and

thus heavily affects their normal population growth. The wise methods needs to be taken to avoid the soap run-off water from washing to come in direct contact with existing water bodies and just to reduce the decline rate of aquatic insects.

1.7 Limit use of artificial light at night (ALAN)

Light pollution during night time has adversely affected the insect population and is increasing at an alarming pace, also in various bio diverse areas it has shown two fold growth [119]. These beautiful and wonderful creatures are attracted to light and thus fall prey to artificial lights either by exhaustion or predation [120]. Analytical work has depicted that nocturnal moth's shows downhill growth in Europe against day flying insects [121]. Reproductive process in fire flies has also drastically affected by the exposure of artificial lights [122]. Artificial lights have completely dominated the life of a common man and the visuals seen on roads, in parks, in malls, cars or other light poles acts as traps for insects.

No doubt such designs and decorations are the foremost need of the modern life but the negative implications of artificial lights upon insects must be kept in consideration. To mitigate the declined insect population, awareness though training camps, social media or via other government agencies should be encouraged among people, to use minimum possible artificial lights or either to stop unnecessary light systems. Moreover government at state level or at national must join hands with light designing experts to discover or design insect friendly light systems to safeguard the future generations of insects where trapping of insects are not needed.

1.7.1 Mass trapping and mating disruption of insects

Mass trapping and mating disruption using pheromone technologies are the latest techniques for pest management [123] as they are species specific technologies as there will be no effect on other close associates in the environment. Besides, no pollution in the environment, no pesticide residues in fruits, secondary pest outbreaks. Though the predators and parasitoids which living and feeding on these target insect pests which are being mass trapped or suppressed in the environment due to mating disruption indirectly affecting the ecological balance and various tritrophic levels.

2. Conclusion

Ecological balance refers when all natural existing system work harmoniously with each other and without having any negative consequences. The completion of these natural systems is achieved only if organisms from microscopic level to giant organisms are taken a good care for their survival. However, the importance and prominence of insects, which falls under kingdom arthropods, are either neglected or unaware by a common man. But to maintain the continuity of life on earth, the role of insects is essential especially the pollination of various plant species. Decline in the growth of insect population has become a societal, scientific, economic challenge for entomologist and researchers. Thus special philosophical, political, scientific, and psychological measures are need of the hour to mitigate the decline of insect population for human survival especially the pollinating, parasitizing and predating insects. Therefore, various methods are presented and defined which would help to mitigate declining population of insects with acceptable levels and to safeguard the rich and healthier future of insects and for the human race.

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