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Global Decline of Insects: A Review from Agricultural Perspective

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ABSTRACT

The diversity and abundance of insect is facing serious challenges globally in the current era. Although the loss of biodiversity other than invertebrates has been a burning issue from a long ago, some recent reports on insect decline and its impact on agriculture have given it a crucial dimension. Studies related to insect decline revealed that 40% of insect taxa are going through the risk of decline. The current situation is the resultant of several human-influenced factors, most prominently the intensification of agriculture. Insect is one of the most diverse groups having immense effects on ecosystem as an integral part of food web which ultimately has direct effect on other organisms of environment. The most conspicuous contribution of insect is its pollination services to 80% of the flowering plants worldwide which have direct effect on human food security. Decline of pollinator insects and natural enemies of insect pests can impair the crop production due to insufficient pollination and underutilization of the insect control potential of predator insects. To resist the vulnerability of nature and to ensure food security, insect decline should be cut down by controlling anthropogenic stressors through the conservation of natural habitats, eliminating deleterious agricultural practices, implementing insect friendly policies, *etc*. Immediate action is necessary to alter the nature exploiting agricultural practices causing insect decline to ensure the normal functioning and integrity of entire ecosystem and for human welfare.

Key words: Agriculture, Biodiversity, Insect taxa, Pollination.

Global decline in biodiversity of many terrestrial and aquatic vertebrates has been a serious issue for a long time; however, insect decline has got the attention recently. Since there are more than a million described species of insects including around 4.5 to 7 million unnamed (Stork, 2018), insects are documented as one of the most abundant and diverse groups of organisms. Recent investigations regarding the decline of insect revealed the importance of insect diversity and abundance for the stability of ecosystem. Sanchez-Bayo and Wyckhuys (2019) recently reported a serious decline in entomofauna which may get worsened within few decades as 40% of the world's insect species can go extinct by this time. Hallmann *et al.* (2017) estimated a seasonal decline of 76% and mid-summer decline of 82% in flying insect biomass between 1989 and 2016 in Germany.

A number of factors coherently linked for causing the loss of insect biodiversity, such as habitat loss through deforestation, use of polluting and harmful substances, intensive agriculture, introduced species, nitrification, pollution and global climate change (Cardoso *et al.* 2020; Wagner *et al.* 2021). Sometimes, multiplicity of factors may be responsible to cause the decline of a single insect population, for instance, the population of domesticated honey bee declined in the United States due to the combined effect of mites, viral infections, microsporidian parasites, poisoning by neonicotinoid and other pesticides, habitat loss, overuse of artificial foods to maintain hives and inbreeding (VanEngelsdorp *et al.* 2012). However, intensive agricultural practice entailing the overuse of chemicals is the most prominent driver of insect decline described by many authors (Kremen *et al.* 2002; Sanchez-Bayo and Wyckhuys, 2019; Wagner, 2020).

The normal functioning of ecosystem as well as humanity is largely dependent on the insect diversity because a number of ecological processes like pollination for more than 80% of the world's flowering plants, controlling of weeds through herbivory, nutrient cycling through degradation of dung and carrion and acting as food source for higher trophic levels including 60% of birds are directly related to insects (Hallmann *et al.* 2017). Loss of insect diversity and abundance can have serious impact on food webs which will ultimately collapse the ecosystem services. Thus, insects possess great significance to the overall functioning and stability of ecosystem.

A major challenge now and in upcoming years is to ensure proper maintenance and enhancement of the components of nature before extracting only benefits from it. Insects play indispensable role in the biosphere, hence they are irreplaceable components in this challenge. Clearly, insect abundance and diversity should attain a prime conservation priority to sustain the nature with ensuring food security for human being. As, along with many factors, human mediated actions in agriculture are enormously responsible for making the condition critical for insect survival, the efforts to mitigate the extent of current loss of

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insect biodiversity are not unapproachable. Therefore, in this review article we will focus on the current trends of insect decline, how the intensive agricultural practices are contributing to this declining trend, its adverse consequences on crop production and the ways to improve the current scenario.

Current status of global insect decline

The report of Dirzo *et al.* (2014) is considered as the first well documentation of the global insect losses for beetles, dragonflies, grasshoppers and butterflies. Several long-term studies across the globe have been done to shed light on the decline of insects of different taxa (Fig 1) and the results supported the fact for 40% of insect taxa (Sanchez-Bayo and Wyckhuys, 2019).

An assessment by Van Swaay *et al.* (2010) on 435 native butterflies of Europe revealed that populations of butterflies particularly in Mediterranean and eastern countries were declining which comprised 19% of total. They found around 8.5% species as threatened and three species namely *Pieris brassicae wollastoni*, *Triphys aphryne* and *Pseudochazara cingovskii* as critically-endangered. In United Kingdom, five species of butterflies have been reported as disappeared completely and 45% of the documented butterflies are listed as being threatened (Warren, 2019; Fox *et al*. 2015). Similar reports on the decline of butterflies and moths are obtained from Asian countries as well. In Japan, among 240 species of butterflies, 15% were reported as threatened by Nakamura (2011). In Malaysia, the abundance of 19% of moths at Mount Kinabalu (Borneo) got reduced over a period of 1965 and 2007 (Chen *et al.* 2011). Singapore faced a reduction of 32% of 413 recorded species of butterflies since 1854 (Theng *et al.* 2020). According to IUCN Bangladesh (2015), butterflies are the most threatened species in Bangladesh with 62% of the 305 known species being listed as nationally threatened. The recognized threats to butterflies in Bangladesh include habitat deterioration, loss of nectar and larval food plants, wide use of chemicals and fertilizers and changes in floristic features (Aich *et al.* 2016; Chowdhury *et al.* 2017).

Bees account for a third of all pollinators of flowering plants; hence, are considered as essential components for global food security (Ollerton *et al.* 2011). Many research reported the worldwide decline of pollinators as a warning for human well-being. In UK, one-quarter of 139 studied bee species was reported to be declined but gladly 10% among them has increased (Powney *et al.* 2019). The number of bees declined in Neotropics as well where deforestation, agricultural expansion and urbanization were thought to be responsible for the decline (Nemesio, 2013). The USA is currently facing an annual decline of 0.9% honey bee population (Ellis, 2012). In southern England, the practice of cultivating clover and legumes in rotations for soil nitrogen was replaced with the use of chemical fertilizers which reduced the population of three species of long-tongued bumblebees (*Bombushu millis, B. ruderatus* and *B. subterraneus*) that used to forage on them (Goulson *et al.* 2005). Among the 60 species and subspecies of studied bumblebees in central Europe, four have become extinct with an alarming decline in the abundance of 48 species over the past 136 years (Kosior *et al.* 2007). Wilson (2002) described tropical deforestation as a leading factor to cause the biodiversity losses for forest-inhabiting species including ants.

McGuinness (2007) documented 36 species of large carabid beetles as declining, while 12 species as endangered in New Zealand. According to IUCN, Odonata is the most endangered aquatic insect group comprising 106 endangered species out of 118 species recorded (Kalkman *et al.* 2010). Schuch *et al.* (2012) observed the population of cricket and grasshopper in Germany's grasslands and found an overall decline of 64% over a period of 1951–2009. In the Netherlands, data on lacewing abundance showed an average annual decline of 4.6% from

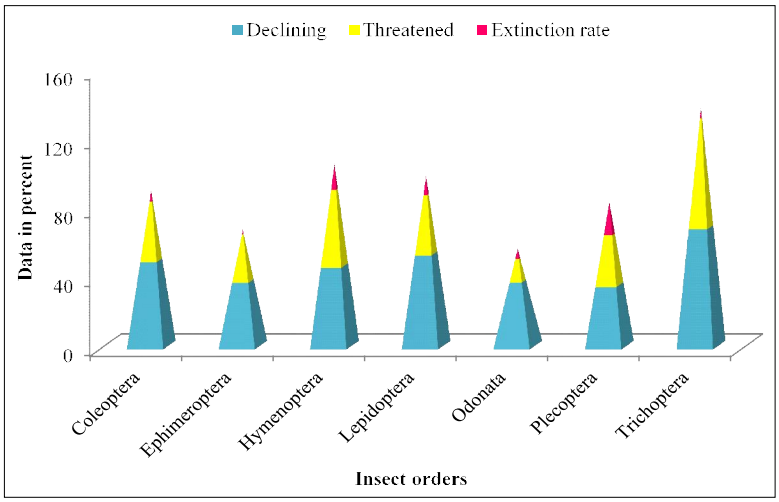

Fig 1: The declining and threatened species of different taxa according to IUCN criteria (> 30% decline) and the regional extinction rate (*i.e.* per cent of species not observed in > 50 years) (derived from Sanchez-Bayo and Wyckhuys, 2019).

2006 to 2017 (Hallmann *et al.* 2020). They also reported the decline of 12% of mayflies (Ephemeroptera) and 9.2% of caddisflies (Trichoptera) by observing the light trapping captures.

Agriculture associated stressors responsible for insect decline

Numerous studies have been done focusing on the factors responsible for insect decline. Results demonstrated that a number of drivers which mainly entail anthropogenic activities contributed to insect decline or extinction. The more devastating factors are land-use change including deforestation, habitat alteration through the use of pesticides, agricultural intensification, urbanization, introduced species, overexploitation, pollution and climate change (Cardoso *et al.* 2020; Sanchez-Bayo and Wyckhuys, 2021; Wagner, 2020; Wagner *et al.* 2021).

Ollerton *et al.* (2014) reported that major insect declines occurred due to the changes in agricultural practice from traditional to modern and low-input farming style to the intensive. For agricultural expansion, deforestation is done which may have effects on forest insects and other arthropods (Raven and Wagner, 2021). Brooks *et al.* (2012) considered the loss of trees and hedgerows as the responsible factor that caused the decline of specialist ground beetles. The removal of weeds and trees may be the reason of the decline of some insect species overwintering in soil (Fox, 2013).

In addition to deforestation, crop monoculture and the removal of tree coverage to facilitate mechanization are responsible for the destruction of insect habitat. Having focus to the higher yield only, intensive agriculture leads to monocultures with genetically uniform plants (Fox *et al.* 2014; Nakanishi *et al.* 2018; Homburg *et al.* 2019). Monoculture of crop is a prominent factor responsible to cause a great simplification of biodiversity among insect pollinators, natural enemies and nutrient recyclers, but create the conducible conditions for agricultural pest. The cultivation of genetically modified or transgenic crop can also have adverse effect on insects. Malone and Pham-Delègue (2001) studied with the effect of transgene products on honey bees and bumblebees and found negative but sub-lethal effects of transgenic pollens in few instances. A number of reports indicated agriculture-related practices as the main stressor of insect declines in both terrestrial and aquatic ecosystem (Sanchez-Bayo and Wyckhuys, 2019).

The current agricultural practices incorporate an extensive use of pesticides and herbicides which have adverse impact on non-target species, insect-plant interactions and the quality of their habitats. Pesticides affect insect population through direct toxicity, sub-lethal effects and habitat alteration. Insect population encounters additional threat due to bioaccumulation and bio-magnification of toxic substances along food chains (Hayes and Hansen, 2017) which can have detrimental effects on insect physiology and behavior (Desneux *et al.* 2007).

In intensive agriculture, to secure more yields the use of chemical fertilizer is increasing. Admixture of fertilizer and sewage to lake water causes the decline of the insects belong to Chironomidae, Trichoptera and Ephemeroptera (Jenderedjian *et al.* 2012). Moreover, the occurrence of nitrification due to the manufacture of a huge amount of reactive nitrogen (mostly for fertilizer) is responsible for the decrease of insect and plant diversity (Habel *et al.* 2019; Pöyry *et al.* 2017). Therefore, the current agricultural practices are considered as the most alarming factor to cause insect decline.

Unfortunate consequences to agriculture due to insect decline

As the most diverse and abundant group, insects comprise much of the animal biomass associated with primary producers and consumers, as well as higher-level consumers in fresh water and terrestrial food webs. As an inseparable part of many trophic links, many insects provide ecosystem services upon which humans depend (Fig 2). The regulatory ecosystem services provided by insects are important particularly for agricultural production, which include herbivory, pollination, seed dispersal and disease control. Therefore, severe insect declines can have devastating impact on crop production which will ultimately affect global ecology as well as economy.

Although the current trend of insect decline entails insects of various taxa, the aforementioned data revealed that the pollinators and predator insects are the most vulnerable groups. According to the research reports, agricultural intensification is the main cause of pollinator decline (Cole *et al.* 2017; Kremen *et al.* 2002) resulting in the reduction of pollination of diverse plant populations (Attwood *et al.* 2008). Not only the food crops, many other crops for fibre, fodder, biofuels, timber, phytopharmaceuticals, as well as ornamental plants also critically rely on pollination service provided by insects (Van der Sluijs and Vaage, 2016).

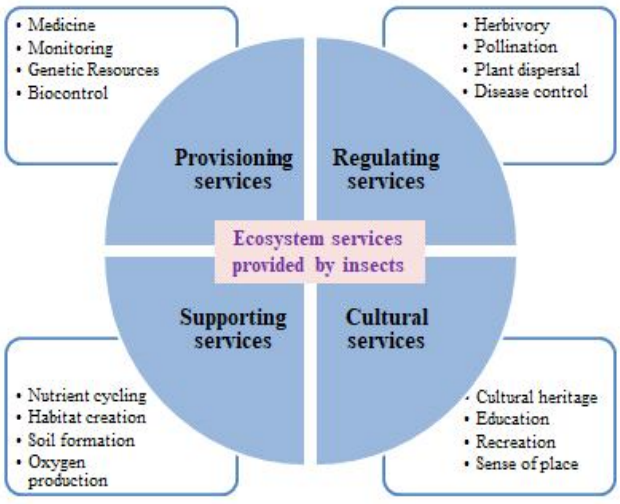

Fig 2: Ecosystem services provided by insects for mankind (derived from Cardoso *et al.* 2020).

Van der Sluijs (2020) suspected that the loss of insect pollinators will critically threaten global food security, can worsen hidden hunger (micronutrient deficiencies) and can make the ecosystems unstable. A modelling analysis found that an absolute removal of pollinators could increase global deaths yearly by about 1.4 million due to non-communicable and malnutrition-related diseases (Smith *et al.* 2015).

The uses of broad-spectrum insecticide particularly affect the ground dwelling insects (Lundgren *et al.* 2015). Application of systemic insecticides reduces the population of agricultural beneficial insects, such as lady bird beetle and butterflies (Krischik *et al.* 2015). The translocation of these insecticides to pollen, nectar and guttation drops has drastic effect on nectar-feeding insects such as bees, butterflies, hoverflies and parasitic wasps (Van der Sluijs *et al*. 2015). In Japan, application of nicotinoids is described as the main culprit for the decline of dragonflies which is an important predator of insect pests of crops (Nakanishi *et al.* 2018). In North America, monarch butterfly decline (*Danaus plexippus*) was correlated to the increasing use of neonicotinoid insecticides (Wilcox *et al.* 2019; Halsch *et al.* 2020).

Biological control using insects is an opportunity to mitigate hundreds of harmful invasive pests worldwide (Heimpel and Cock, 2018; Hajek *et al.* 2016; Hoddle, 2004). Classical and augmentative biological control and habitat management practices to promote insects as natural enemies of pests are much praised efforts in current agriculture. In this context, as a clear consequence, insect declines can negatively affect the management of pest population which ultimately will affect the maintenance of food supply for human beings. Møller (2019) also reported that the parasitoids and predators which directly rely on insects are affected by insect decline. Sometimes pest management strategy is adopted based on the presence of predators to obtain pest suppression potential. Harmon *et al.* (2006) reported that the management strategies against aphid on alfalfa is employed based on both aphid and coccinellid densities. Thus, the loss of particular predator species can result in lower efficiency of applied other management approaches.

Reforming the existing agricultural practices towards insect conservation

Based on available records and data on the abundance, diversity and richness of amphibians, birds, flowering plants, mammals, reptiles, insects and other taxa, global biodiversity loss can no longer be ignored. This crisis is accelerating as the human population grows making increased pressure on nature to fulfill human demands (Wagner *et al.* 2021). Things are getting to the point where we cannot remain reckless anymore and we need to take urgent action to protect our living world.

Many promising solutions are now available to support insect populations at sustainable levels among which preservation of the natural habitats of insects should get the priority. Other realistic solutions can be the elimination of destructive agricultural practices including indiscriminate use of pesticides, extensive use of chemical fertilizers, *etc.* The application of chemical fertilizer can be taken under control by adopting and implementing alternative methods; for instance, use of organic fertilizers, incorporation of green manure, precision agricultural practices, *etc.* It is reported that organic farming plays a positive role to sustain biodiversity and enhance insect population with a balanced manner (Garibaldi *et al.* 2019).

Integrated pest management approaches may be imperative to mitigate the wide spectrum use of chemical pesticides. Many biological and nature friendly insect control measures are now available and much praised everywhere. Mass trapping and mating disruption using pheromone technologies are such kind of techniques of pest management which are species specific and thus have less effect on non-target insects (Hussain *et al.* 2015).

The expansion of agriculture by destroying forest land, especially in the tropics should be brought under control (Warren *et al.* 2021). Funding to support insect conservation research should be encouraged where the pollinator section should get the prime concern. Proper legislation should be developed and executed to restrict the use of some pesticides which lead to the toxicity of nectar and pollen of the plants for the non-target flower visiting insects.

Many countries in the world have already started paying proper attention to conserve insect biodiversity by adopting concrete measures. For instance, many European countries are banning and restricting the use of glyphosate-based weed killers. Since many solutions are now at our hand, we need to act upon them promptly (Cardoso *et al.* 2020; Samways *et al.* 2020). Along with provisioning of proper research, scientists can contribute to insect conservation by educating a wider population about the ecological, economic and scientific value of arthropods and finding ways to integrate insects and other arthropods into the same frame of daily human life (Kawahara *et al.* 2021). Major focus should be given to protect the pollinator insects and natural enemies of pests while reducing the extensive use of pesticides and chemical fertilizers.

CONCLUSION

There is no scope to deny that the biodiversity of insect is declining worldwide. Although multiple stressors sticking together are responsible to cause insect decline, the areas where there is high human activity, insect declining rate is conspicuous. As the insects are compactly linked with countless number of food webs of ecosystem and human beings are directly dependent on their pollination services for food, we cannot but think of any other solution without conserving the insects. Therefore, a more general understanding of the value of insects, in terms of ecosystem services, human wellbeing and the betterment of our living world is a crying need in present situation.

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