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Insect Annihilation: Causes for Decline and Strategic Conservation Plan in 21st Century

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***Abstract*:** Insects are “six-legged companions”, whereas annihilation is a collective term “event involving in sudden decline or damage on the catastrophic scale due to *Anthropocene.* The decline that may lead to the extinction of 40 percent of the global insect species over the next few decades. pollinators, bees, wasps, beetle populations, terrestrial taxa, and aquatic insects including dragonfly, damselfly, stonefies, mayfly, and caddisfly have lost a substantial proportion of species in the last decades. The main drivers of species declines are change in climate at global leval, intensive agriculture, urbanization, pollution, loss of habitat and biological factors etc. Time is too short for conserving the necessary insect diversity to sustain us. There are six interrelated themes for conservation methods to ensure that insects survive into the twenty-first century and beyond.

Keywords: Arthropods dereases, Climate change, Pollution, Biological factors, Conservation

Insects are referred to as "six-legged companions" whereas annihilation is defined as a "castrotrophic scale event caused by the Anthropocene." According to scientific studies, insect populations have been falling internationally for decades (Wagner et al 2021). Regulations and public concern regarding insect loss have been scarce and mainly neglected since the dawn of civilization. There are approximately 5.5 million insect species in the globe, with 90 percent of these species undiscovered and their biological purpose unknown. Decling of insect species is a major problem due to their ampleness, diversification and extinction of an entire species richness. The word "population decline" refers to both a decrease in insect numbers and a reduction in geographic distribution, which is the first step toward extinction (Sanchezbayo and Wyckhuys 2019). The causes and patterns of insect decline differ according on the region's biotic, abiotic, and anthropogenic factors. The causes are debatable, although they almost certainly include habitat loss, pesticide exposure, pollution, climate change, biological factors, and technology interventions as primary drivers of arthropod decrease (Samways et al 2020). The effects are clear: insects are a vital element of the food chain, providing food for a variety of lower and higher organisms while also aiding in biological pest control, act as pollinator and nutrient recycling. The terrestrial and freshwater ecosystems would collapse without this tiny creatues. The current review is organised into several subsections that describe the timeline of mass extinction events on Earth, followed by the current scenario of insect decrease, primary drivers of insect decline, and conservation activity toward the arthropod community to save little creatures from extinction.

Services to ecology and economy: Insects serve an important part in maintaining environmental equilibrium. They are necessary for the survival of the ecosystem. They recycle the nutrients, pollinate the plants, dispersal of seeds, maintain the soil structure and fertility, manage some other organism populations and serve as a primary food source in the food chain. Insects pollinate over 80% of the blooming plants on Earth (Noriega et al 2018). The pollinators include solitary bees, squash bees, honey bees, bumble bees, beetles, flies and butterflies. Many of the birds, reptiles, bats, tiny mammals, amphibians and fish would become extinct if insects did not exist. About 87 percent of all plant species require animal pollination, with insects providing the majority of it (Ollerton et al 2011). Insects improve the soil structure and make it fertile by decomposition and consuming dung. The dung beetles feed partly or exclusively on dungs or faeces and protect the livestock by removing dungs, if not done it may facilitate a habitat for flies. In many countries, this beetle was introduced the for the goodness of animal husbandry. Insects are an important part of the food chain and predator such as lacewings, ladybird beetles and parasite wasps should helps to control other arthropods and vertebrates. The *Neuroptera* larvae of insects like lacewings owlflies, antlions, mantidflies, snakeflies, spongeflies and dobsonflies that help as predator for controlling insect pests

like aphids, leaf hoppers, mites, scale insects, beetles and caterpillars as successful biological control ever. Insects are economically important because they provide honey, shellac, wax, silk and other products. Edible insect species about 1500 were consumed and 3000 by indigenious pepole in 113 countries globally. Grasshoppers, ants beetles, cicadas, bugs, and caterpillars are protein rich nutrient consumed by large number of people. So, insects are the indicators of the healthy ecosystem.

Big five mass extinction have shaped the earth: Among the many unexplained events and mysterious that have occurred on earth over the millions of years. The rapid loss of biodiversity is called as Mass extinction. These events have left earth open to evolutionary changes as new species emerge to replace those that have died. At least five different mass extinctions, known as the Big 5, have been discovered.throughout history about lost 50 to 75% of life was lost. (Gemmatarlach 2018) (Table 1).

Extinction today and current estimates of decline globally*:* Earth is currently experiencing a biodiversity crisis. According to the study, more than 40 percent of arthropod species get lost and one-third are in endangerous line. The extinction rate was eight times that of mammals, birds, and reptiles. Based on the available data, estimated number of insects is decreasing at 2.5 percent per year. This data indicate that they may become extinct within a century. Since we are in 20th century, there has been an increase in Holocene extinction of species, with 95 per cent decline due to Anthropocene. ZSL - Zoological Society of London (2012) reported that vertebrates that is the stating point of insect species decline and 20% of all invertebrates are in grave riskier of extinction globally, with both direct and indirect consequences. Some research found a huge gap of data exist between 1840 and future predictions. due to the global concern about species extinction, the German Nature Reserve gained a lot of attention in 2017 and obtained 27-year long population monitoring study revealed a shocking prediction about 76% decline in flying insect biomass at several of parts Germany's protected areas of global concern about species extinction (Hallmann et al 2017). This equates to 2.8 percent insect biomass loss per year on average . Sadly, the study reveals a consistent downward trend over the three decades. A recent study in Puerto Rican rainforests discovered biomass losses of 98 to 78% for soil dewellling and canopy-dwelling arthropods over a 36-year period, with annual losses of 2.7 to 2.2% (Lister and Garcia 2018). The latter its was reported by many researchers, there was a parallel decline in birds, frogs and lizards which in turn results of food shortages for invertebrate. Those reports were agreeed with the decreasing pattern for aerial flying population (includes house flies, mosquiotes, etc.) observed in earlier parts of Southern Britain. The IUCN Red List, for example, includes only 8400 species on that one million described and 0.2 percent of all extant species. However, that the insect extinctions have been around 5 to 10% since the industrial era, ranged from 2,50,000 to 5,00,000 species (Regnier et al 2015). At least one million species, half of which are insects, are on the verge of extinction in the next ten years (Diaz 2019). Inspite of this 15,000 scientists were signed and humans are factor for "pushing natures tiny beauty beyond their capacity to support the web of life. "Group of entomologists and ecologist worrying about the global vanish of arthropod groups, discussed about insect extinctions, their causes, and the impact they have on

Table 1. Mass extinction events and species lost

Extinction events (Million years ago)	Size of the extinction and species lost	Suspected causes
Ordovician-Silurian extinction- Paleozoic Era (440 MYA)	• 85% of all living species eliminated • Marine genera- trilobites, shelled brachiopods, eel-like conodonts, graptolites were died off	Climate change, glaciation and continental drift. Among the major extinction this alone linked with global cooling.
Late Devonian extinction - Paleozoic Era (375MYA)	• 80% of all living species lost • Vascular plants, such as trees and flowers genera were gone extinct.	Volcanic eruptions, quick cooling of air temperatures, lack of oxygen in the oceans.
Permian Mass Extinctions - Paleozoic Era (250 MYA)	• 96% of all living species eliminated • 95 % marine species and 70% land-dwelling vertebrates	Massive volcanic eruptions, Climate change (Carbon dioxide - Bacteria - Methane) Well known largest extinction of insects
Triassic-Jurassic Extinction- Triassic Period of Mesozoic Era (200 MYA)	• More than half of all living species eliminated • Marine and large amphibians related to crocodiles and dinosaur's species got vanished	Reason behind this extinction about volcanic activity with basalt flooding, changing in pH and sea levels at oceans and climate change over longer period,
K-T Mass Extinctions Cretaceous Period of the Mesozoic Era (65 MYA)	• 75% of all living species eliminated • Extinction of mammals, birds, amphibians, reptiles, and insects. Marine reptiles like mosasaurs, plesiosaurs and ammonites were badly affected	Extreme asteroid or meteor impact

Now: The Holocene Extinction

humans. We conclude with a call for instant measures to address our knowledge gaps and prevent insect extinctions.

Are we next?: The question of whether or not the earth is on the verge of another mass extinction has sparked heated debate among scientists. This time, however, neither natural calamities nor valconic reuptions are to blame. Anthropocene were causing a global climate change have accelerated the vanishing of species by ten to one hundred times faster than expected. The scientific proofs were precise: people have been approaching the sixth mass extinction as a result of the Anthropocene "age of humans," in which human activity has impacted climate and environmental trends, leading to insect decline and, as a result, driving us, *Homo sapiens*, down the path to extinction (Cardoso et al 2020)

Drivers of the Declines

Habitat change: Habitat change is the primary cause of insect declines, accounting for 49.7% of all insect declines and having an equal impact on global bird and mammal declines (Chamberlain and Fuller 2000). Pollution (25.8%) followed by biological factors (17.6%), and next to that is climate change (6.9%) are the next most common causes of loss.

Agriculture intensification: Changes in agriculture intensification, deforestation, urbanisation, mining, industrialization, and extractive land uses all contribute to habitat change in the local environmental conditions in which a particular organism lives, which is the greatest current threat to global biodiversity. With agricultural transformation and expansion (24%), urbanisation (11 %), deforestation (9 %), and others (5 %), landscape fragmentation is undoubtedly the leading cause of species diminish (Sanchezbayo and Wyckhuys 2019, Mittermeier et al (2004) found that 50 percent of endemic plant and vertebrate species are restricted to 36 biodiversity hotspots covering only 2.5 percent of the planet, and these hotspots are likely to cover similar percentages of endemic insect diversity (Stork and Habel 2014). Green revolution often leads to larger in extent involved in use of monoculture, high yielding varieties, high use of pesticides and fertilisers, growing of GMO crops that produce insect toxins are all factors that contribute to insect decline. Specialist pollinators like many of bumblebees and wild bees to land-use changes involving loss of floral resources, nesting and hibernation sites known to be a threat factor to bee's decline (Williams and Osborne 2009). For specialist predators like ground beetles, improved irrigation facilities, loss of hedgerows and trees are trigger towards decline of this species (Brooks et al 2012). Agricultural conservation causes stream channelization, wetlands drainage, floodplain modification, and riparian canopy removal, all of which result in soil and nutrient loss, homogenising stream microhabitats and altering aquatic insect communities (Houghton and Holzenthal 2010). Eutrophication resulting in a decrease in diversity of insect such as dragonflies and damselflies aquatic ecosystem for their naiads development. Odonata makes up 106 of the 118 aquatic insect species are in endangered list given by the IUCN (Sahlen et al 2010).

Intensive agriculture involves widespread use of pesticides for controlling crop pests (13 % insecticides), use of fertilizers (10%), killing weeds (herbicides) and diseases (fungicides) (Dudley and Alexander 2017). Most taxa suffered are moth, pollinators, ground dwellers, foliage feeders, lady birds, butterflies, aquatic life., etc. The loss of flying insects like butterfly, dragonfly, etc., and pollinator communities were directly linked to aerial pesticide application. Pesticide use is one of the primary causes of insect decline. This 2nd Silent Spring where neonics are similar to a new DDT, but they are a thousand times more toxic to bees. Neonic pesticides are a major cause of the 'insect decline,' with a 40% loss due to widespread use of this compound. Because of the widespread use of neonicotinoid pesticides, Honeybees are now more toxic (48 times) in America's farming than in last five years. Meta analysis on 17 widespread and resident species of butterflies between 1984 and 2012 showed that abundance of all species decreased by 58% since from 2000, while 15 species exhibited population declines high proportions of farmland treated with neonicotinoid insecticides at average annual rates between −0.8% and −6.7% (Gilburn et al 2015). Insecticides such as neonicotinoids and fipronil both impair the reproductive performance of queens and drones, jeopardising the long-term viability of entire colonies. Merging of chromium and neonicotinoids are more toxic to bees, and the metal had an antagonistic effect on fungicide toxicity (Kairo et al 2017, Sgolastra et al 2018). Neonics are not only extremely toxic to honeybees, but they can also persist in the environment for over 1,000 days. Plants absorbed systemic insecticide during foliar as well as soil application, those toxins were incorporated into leaves, stems, pollen, nectar, sap, etc. Pollen and nectar translocation have an impact on bees, butterflies, hoverflies, and wasps (Vandersluijs et al 2015). Because of their high acute and chronic toxicity, pyrethroid, neonicotinoid, and fipronil insecticides have a devastating impact on aquatic insects and crustaceans, as well as reducing the development of chironomids and other insect larvae, with negative cascading effects on fish survival (Weston et al 2015, Kasai et al 2016). Impair larval viability, undermine the insect food web, natural biological control mechanisms happenings in the ecosystem, and persistent residues in sediments inhibit emergence and do not allow aquatic nymph recovery, contributing to the decline (Jinguji et

al 2013). Dragonflies, trichoptera, and ephemeroptera have also been harmed by surface water eutrophication caused by excessive fertiliser use in rural areas. The treatment of livestock with persistent avermectins and insect growth regulators has contributed to a reduction of dung beetles in most of the countries, as residues of these pesticides in dung pats eliminate the developing larvae. Unfortunately, more tolerant species of Ceratopogonidae and Psychodidae flies that breed in the same pats had their numbers boosted in Japan (Iwasa et al 2005). Combination of Azole fungicide and lambda cyhalothrin leads to Collapse to honey bees (Simondelso et al 2014).

Genetically modified organisam (GMO) crops are those that use of any plants, animlas other microorganisams where its DNA modified, have been incroprated modified new trait from one organisam into other. Usage of this GMO crops buildup insecticide and insect resistance to pests and diseases. But growing of GMO crops serious threates for fall off insect population. Massive use of glyphosate (Round up), the toxic weed killer widely sprayed on GMO crops. The widespread use of glyphosate has decimated the milkweed plants on which monarch butterflies lay their eggs (Belsky and Joshi 2018). According to the study, the dwindling monarch population is due to reduction in breeding habitat, particularly in the United States. Between 1999 and 2014, milkweed declined by 40%, while potential monarch host capacity fell by 71%. It concludes that monarch butterflies in the United States may become extinct within the next two decades, owing largely to the widespread use of herbicides with genetically modified corn and soybeans. GMO soya is grown in Amazonian Brazil for the European market, destroying insect diversity in the Amazon (GMO 2016)

Urbanization: Globally, urbanisation is increasing, resulting in destruction of habitat and large habitats are being reduced to smaller areas. Natural habitats are being lost and fragmented as landscapes become more urbanised. Potentially harmful consequences for biodiversity. The Xerces blue butterfly, *Glaucopsyche xerces* gone extinct only due to habitat conversion and urban development main reason. The visiting of the honey-bee populations in disposed cups in commercial beverage shops in rural and urban areas was observed. Honey bee populations that visit these artificial cups for an average of 1225 cups per day never return to their hives. It was recored that 168 bees/ day were visiting and 25,211 dead bees in 30 days, incase of dammer bees (48 bees-single cup/ day). These cups act as 'death traps' for the bees as they fall into the cups and get enmeshed in the syrupy residues, thereby becoming unable to fly out research carried out during 2010 (Chandrasekran et al 2011, Sandilyan 2014)

Deforestation: The total forest area in the world is estimated to be around 4.06 billion hectares. Forests cover 31% of the earth's surface, and from 1990 to 2020, 20 million acres of forest were lost with 2400 trees being cut down every minute. The country's total forest and tree cover is 80.73 million hectares, with a 24.56 percent loss due to tree cutting. India lost 38.5 thousand hectares (14 % loss) of tropical forest in 2019-20. Deforestation is the primary cause of saproxylic beetle extinction in Europe (Nieto and Alexander 2010).

Pollution: Pollution is the second leading cause of insect extinction. Mining of metals, smelting, and other metal-based industries, as well as leaching of metals from various sources such as hazardous waste, toxic waste, garbage dumps, and other metal-based industries, have all contributed to heavy metal pollution.These heavy metals accumulate in the air and spread to agricultural crops in the vicinity of industrialised areas. Critical pollinators, such as honey bees, are directly exposed to metal pollutants when foraging on contaminated nectar and pollen (Xun et al 2018) and suffer from changing behaviour, memory loss, irregular heartbeat, finally dementia when exposed to metal pollution like aluminium (Al) present about upto 200 ppm in sample collected and cadmium (Cd) and Cu compared to unexposed bees (Nisbet et al 2018). Bees are sensitive to lots of toxins 80% reduction in pollinator survival (Thimmegowda et al 2020). One in six species of bees gone extinct in various regions throughout the world. The night-time darkness is a threat to many nocturnal creatures as global light pollution rises. Artificial light “significantly suppressed” the courtship of firefly pairs (Elgert et al 2020). Studies reported that insect population was reduced in hedgerows (47 %) and grassy areas (37 %) along the roadside, because of more use of LEDs lights and this not only disrupt arthropods activities but also contribute to their decline. Nocturnal dung beetle uses moon light from the Milky Way to orient itself but illumination of building lights obscures the dung beetle from galaxy (Foster et al 2021)

Biological factors: Introduction to invasive species found to be on threat on the existing population. Establishment of non native plants leads to reducton of arthropod herbivore loads higher than 90%. The Spread of *Varroa destructor* mite and the small hive beetle, *Aethina tumida* at global leval affects apicultural industry because they transmit viral infections (Vanengelsdorp et al 2012). Through processes like direct predation and parasitism, exotic species introduced for biological control can contribute to the extinction of endemic insects. Planting of exotic trees species along the river's edge of many countries have also impacted negatively on the diversity of dragonflies (Clausnitzer et al 2009). Mosquito control with the larvicide *Bacillus thuringiensis israelensis* (Bti) is still a source of contention, particularly when it comes

to the negative effects on non-target organisms such as non-biting midges, of which 50 to 80 percent were killed (Allgeier et al 2019)

Climate change: Ecologists and conservationists are currently working to connect the climatic change that is killing Earth's smallest creatures. Climate change is one of the factors contributing to the decline of butterflies and wild bees (Samways et al 2020). The Paris Agreement is a legally aims to keep deadline for climate change global at one point five degree celcius (1.5°C) rather than earlier aim of two degree celcius (2°C). Climate change determined geographic span dropping to higher than fifty per cent and are projected in vertebrates (26%), plants (44%) and insects (49%), under current pledges, corresponding to 3.2°C warming. At 2°C, reduced to insects (18%), plants (16%), and vertebrates (8%), while at 1.5°C, insects drop to (6%), plants (8%), and vertebrates (4%). When warming is limited to 1.5°C rather than 2°C, the number of species projected to lose more than half of their range is reduced by 66 percent in insects and 50 percent in plants and vertebrates (Warren et al., 2018). Increasing the amount of co2 in the atmosphere, thereby amplifying the Earth's natural greenhouse effect this was happening due much of human activities and makes the earths loosing its small creature. Dung beetles become smaller as CO2 levels rise in the atmosphere. Increased CO_2 in the atmosphere makes dung beetles smaller (Tocco et al 2021). Carbon dioxide levels in the atmosphere are rising, which reduces monarch tolerance and increases parasite virulence by altering the medicinal properties of milkweeds (Dicker et al 2018)

Technological interventions: Mobile telecommunication antenna emits electromagnetic radiation which influences the abundance and composition of wild pollinators. The radiation emitted by towers may impair honey bee navigational skills, preventing them from returning to their hives (Taye et al 2017)

Insects' conservation in 21st century are six interrelated themes: The world is in trouble, as evidenced by the publication of "World Scientists' Warning to Humanity: A Second Notice" (Ripple et al 2017). We must take decisive action on how we manage the planet right now. The future insect diversity should depend on-site adoption, travel through the human-created barriers and final is to die out. It is not an ethical or survival option for insects or humans to go extinct; instead, we must develop conservation methods to ensure that insects survive into the twenty-first century and beyond (Samways 2018):

Theme 1 - Philosophy for insect conservation: First theme implies that we should have intrinsic value on insects, which in turn these insects provide benefits for us in form of bringing bring peace, create mental well-being while seeing these little creatures in the parks, gardens, etc., and also give resources. Because without them, as resources begin to drop, the world would become barren and moving to precarious situation .Simply, we need to look after insects, and they will look after us (Samways 2018)

Theme 2 - Research needed for 21st century insect conservation: Insect conservation research at the operational level focuses on developing new and effective methods for preserving insect diversity, species, and populations. From the standpoint of conservation at species-level, “a species” are the group of individuals in populations, do or do not, interchange of genes. There are two type of population metapopulations and sub population. The viability of populations depending on the flow of genes help them for adapting to existing conditions, but adversely affected by land use fragmentation, insecticidal usage etc. Metapopulation can be affected if gene flow is improper, resulting in an adapt-or-die situation. While subpopulations, the situation is different because they are already separated due to natural barriers. Evolutionarily significant units (ESUs) includes various subpopulations and each units were deserving to be continued existence on its own. *Lycaena dispar dispar* gone extinct, *L. dispar batavus* were under threatened and *L. dispar rutilis* is common and expanding its geographical distribution (Lindman et al., 2015). Despite the fact that ESUs have been reintroduced and should be protected, but it is not real evolutionarily significant units. Genetical research has reported on some species are extremely old, and these species should be protected. Species that have vanished can be resurrected from museum specimens that have been well-preserved. Creating resilient landscapes level conservation with improved functional connectivity, friendly farming system for wildlife which will be resulting in biodiversity friendly in urban areas are the three principles guiding toward insect conservation. Putting people at the centre of environmental issues and growing natural capital could not only continuing to increase the diversity of indigenous species, but also raising the unlimited supply of the focal species. A ten-fold increase would be fantastic for rare and threatened species, while a 100-fold increase would be fantastic for service-providing species like bees for pollination and parasitoids for pest control (Samways, 2018)In the twenty-first century, more research is needed to tailor these principles to local circumstances.

Theme 3- Policy for insect conservation: In terms of policy include dual approaches to conserve insects. Six legged camponion are the part of ecosystem and they also provide important essential services at the national and local levels.

The Aichi biodiversity targets and Convention on Biological Diversity which are specific to insect conservation, whereas for species level conservation, the IUCN provides global level red book list includes insects and NBSAPs -National Biodiversity Strategy Action Plans are working at local level particularly in hotspots areas. Millennium Ecosystem Assessment (MEA) include provisioning, regulating, and cultural services currently provided by insects, which include human consumption of insects and insect therapy, which is becoming increasingly popular globally (Gerlach 2012)

Theme 4-Insect conservation psychology: The relationship between humans and insects is known as insect conservation psychology. Insect conservation is critical to our well-being. Citizen science is the involvement of the general public in the recording, monitoring, and conservation of insects. They activity encourages people to participate in ensuring the future of insects. Insect icons are insects that we are drawn to as children, such as bees, butterflies, and ladybirds. However, not all insects are iconic. Adults, as we grew older, forgot about them in our busy lives. Whlile growing older we will realise that the flies are filthy, the mosquitoes were bother, unwanted and unworthy towards conservational aspects. But we have a pollinator decrease at globally and "the bees were dying," these aspects of realisation is now changing for the better conservation. Another fact is that we are all afflicted with Biophobia. When we overcome our fear of insects, we develop a cultural biophilia for them. Besides biophobia, the another fear factor concerning that there is a loss of essential services particularly pollination done by bees, butterfly, etc. Our reaction to this service loss, alongside biophilia for certain species, is feeding back into insect conservation, which, in turn boosts our sense of happiness. This approach is going to become increasingly important in the twenty-first century (Clayton and Myers 2010)

Theme 5-Insect conservation in practice: Insect conservation is a hands-on activity that relies on solid research and knowledge. In practise, various organisational communities work to conserve insects (Samways, 2018). Many specialist species rely particulat environment to live, so should simulate natural events, these areas require some management. These approaches include eco-friendly agriculture that is organic farming usage of pesticide free cropping, schemes related to agriculture, renovation, eliminate invasive plants species and betterment in urban areas.

Theme 6-*Authentication:* Finally authentication, where we must assess our performance after we have engaged in insect conservation. Determined goal and conducted the research should be done prior to the conservation action and should put research findings into practise, by engaging more in insect conservation psychology. Finally, authentication is a cyclic pathway of success which includes determining resources to achieve the goal, authenticating the goal, and detecting missteps, understanding those missteps in each stage of cyclic pathway, and returning to putting some changes in the goal, and so on. In short, as the twenty-first century progresses, we will place a greater emphasis on a healthy and reliable environment for insect conservation (Samways and Pryke 2016).

CONCLUSION

Ecological balance is the state in which all naturally occurring systems coexist peacefully and without suffering any negative impacts. The wholeness of these natural systems can only be attained if all species, from the smallest to the largest, are given proper attention to ensure their survival. However, the average person either ignores or isn't aware of the significance and prevalence of insects, which belong to the kingdom Arthropoda. However, insects have a crucial role in maintaining the continuation of life on Earth, particularly in the pollination of different plant types. For entomologists and academics, the decline in the increase of the insect population has emerged as a social, scientific, and economic concern. “If we were to wipe out insects alone on this planet, the rest of the life and humanity with it would mostly disappear from land within a few months” said by E. O. Wilson. Time is short for conserving insect diversity so we should take immediate measures to conserve biodiversity. “If conservation of natural resources goes wrong nothing else will go right”, by M. S. Swaminathan.

REFERENCES

Allgeier S, Kästel A and Brühl CA 2019. Adverse effects of mosquito control using Bacillus thuringiensis var. israelensis: Reduced chironomid abundances in mesocosm, semi-field and field studies. *Ecotoxicology and Environmental Safety* **169**: 786-796.

Belsky J and Joshi NK 2018. Assessing role of major drivers in recent decline of monarch butterfly population in North America. *Frontiers in Environmental Science* **6**: 86.

Brooks DR, Bater JE, Clark SJ, Monteith DT, Andrews C, Corbett SJ, Beaumont DA and Chapman JW 2012. Large carabid beetle declines in a United Kingdom monitoring network increases evidence for a widespread loss in insect biodiversity. *Journal of applied Ecology* **49**(5): 1009-1019.

Cardoso P. Barton PS, Birkhofer K, Chichorro F, Deacon C, Fartmann T, Gaigher R, Habel JC, Hallmann CA and Samways MJ 2020. Scientists' warning to humanity on insect extinctions. *Biological conservation* **242**:108426.

Chandrasekaran S, Arunnagendran N, Krishnankutty N, Pandiaraja D, Saravanan S Kamaladhasan N and Kamalakannan B 2011. Disposed paper cups and declining bees. *Current science* **101**(10): 1262

Clausnitzer VV, Kalkman J, Ram M, Collen B, Baillie JE, Bedjanic M, Darwall WRT, Dijkstra KDB, Dow R, Hawking J, Karube H, Malikova E, Paulson DK, Schütte F, Suhling RJ, Villanueva N,

Vonellenrieder and Wilson K 2009. Odonata enter the biodiversity crisis debate: the first global assessment of an insect group. *Biol. Conserv*ation **142**: 1864-1869.

Chamberlain DE and Fuller RJ 2000. Local extinctions and changes in species richness of lowland farmland birds in England and Wales in relation to recent changes in agricultural land-use. *Agriculture Ecosystem Environment* **78**: 1-17.

Clayton S and Myers G 2010. Conservation psychology: understanding and promoting human care for nature. *Environmental Conservation Foundation for Environmental Conservation* **37**(2): 222-225.

Diaz S, Settele J, Brondízio ES, Ngo H, Gueze M, Agard J, Arneth A, Balvanera P, Brauman K, Butchart SH and Zayas C 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, Bonn, Germany, Pp, 1-56.

Decker LE, de Roode JC and Hunter MD 2018. Elevated atmospheric concentrations of carbon dioxide reduce monarch tolerance and increase parasite virulence by altering the medicinal properties of milkweeds. *Ecology Letters* **21**(9): 1353-1363.

Dudley N and Alexander S 2017. Agriculture and biodiversity: A review. *Biodiversity* **18**(2-3): 45-49.

Elgert C, Hopkins J, Kaitala A and Candolin U 2020. Reproduction under light pollution: Maladaptive response to spatial variation in artificial light in a glow-worm. *Proceedings of the Royal Society B* **287**(1931): 20200806.

Foster JJ, Tocco C, Smolka J, Khaldy L, Baird E, Byrne M, Nilsson DE and Dacke M 2021. Light pollution forces a change in dung beetle orientation behavior. *Current Biology* **31**(17): 3935-3942.

Gemmatarlach 2018. *The Five Mass Extinctions That Have Swept Our Planet*. Planet earth, Magazine Newsletter.1p

Gerlach J 2012. Red Listing reveals the true state of biodiversity: a comprehensive assessment of Seychelles biodiversity. *Phelsuma* **20**(2012): 9-22.

Gilburn AS, Bunnefeld N, Wilson JM, Botham MS, Brereton TM, Fox R and Goulson D 2015. Are neonicotinoid insecticides driving declines of widespread butterflies?. *Peer J.* **3**:e1402.

GMO - https://reporterbrasil.org.br/documentos/amazonsoya.pdf, 2006

Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, Stenmans, Mülle A, Sumser H, Hörren T, Goulson D and Dekroon H 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLoS One* **12***:* e0185809.

Houghton DC and Holzenthal RW 2010. Historical and contemporary biological diversity of Minnesota caddisflies: A case study of landscape-level species loss and trophic composition shift. *Journal of the North American Benthological Society* **29**(2): 480-495.

Iwasa M, Nakamura T, Fukaki K and Yamashita N 2005. Nontarget effects of ivermectin on coprophagous insects in Japan. Environmental Entomology **34**(6): 1485-1492.

Jinguji H, Thuyet DQ, Uéda T and Watanabe H 2013. Effect of imidacloprid and fipronil pesticide application on Sympetrum infuscatum (Libellulidae: Odonata) larvae and adults. *Paddy and Water Environment* **11**(1): 277-284.

Kairo G, Poquet Y, Haji H, Tchamitchian S, Cousin M, Bonnet M, Pelissier M, Kretzschmar A, Belzunces LP and Brunet JL 2017. Assessment of the toxic effect of pesticides on honey bee drone fertility using laboratory and semifield approaches: A case study of fipronil. *Environmental Toxicology and Chemistry* **36**(9): 2345-2351.

Kasai A, Hayashi TI, Ohnishi H, Suzuki K, Hayasaka D and Goka K 2016. Fipronil application on rice paddy fields reduces densities of common skimmer and scarlet skimmer. *Scientific Reports* **6**(1): 1-10.

Lindman L, Remm J, Saksing K, Sober V, Ounap E and Tammaru T 2015. Lycaena dispar on its northern distribution limit: an expansive generalist. *Insect Conservation and Diversity* **8**(1): 3-16.

Lister BC and Garcia A 2018. Climate-driven declines in arthropod abundance restructure a rainforest food web. *Proceedings of the National Academy of Sciences* **115**(44): E10397-E10406.

Mittermeier RA, Gil PR, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, Da Fonseca GAB and Saligmann PA 2004. Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions cemex. *Mexico City*, 392p.

Nieto A and Alexander KN 2010. European red list of saproxylic beetles.

Nisbet C, Guler A, OrmancÄ N and Cenesiz S 2018. Preventive action of zinc against heavy metals toxicity in honeybee. *African Journal of Biochemistry Research* **12**(1): 1-6.

Noriega JA, Hortal J, Azcárate FM, Berg MP, Bonada N, Briones MJ, Del Toro I, Goulson D, Ibanez S, Landis DA, and Moretti M 2018. Research trends in ecosystem services provided by insects. *Basic and Applied Ecology* **26**: 8-23.

Ollerton J, Winfree R and Tarrant S 2011. How many flowering plants are pollinated by animals?. *Oikos* **120**(3), 321-326.

Regnier C, Achaz G, Lambert A, Cowie RH, Bouchet P and Fontaine B 2015. Mass extinction in poorly known taxa. *PNAS* **112**: 7761-7766.

Ripple WJ, Wolf C, Newsome TM, Galetti M, Alamgir M, Crist E, Mahmoud MI, and Laurance WF 2017. 15,364 scientist signatories from 184 countries (2017) World scientists' warning to humanity: A second notice. *BioScience* **67**(12): 1026-1028.

Sahlen G, Kalkman VJ, Boudot JP, Bernard R, Conze KJ, De Knijf G, Dyatlova E, Ferreira S, Jovic M, Ott J and Riservato E 2010. *European red list of dragonflies*. Publications Office of the European Union.

Samway MJ 2018. Insect conservation for the twenty-first century. In *Insect science-diversity, conservation and nutrition*. IntechOpen. Pp, 4-19

Samways MJ and Pryke JS 2016. Large-scale ecological networks do work in an ecologically complex biodiversity hotspot. *Ambio* **45**(2), 161-172.

Samways MJ, Barton PS, Birkhofer K, Chichorro F, Deacon C, Fartmann T, ... and Cardoso P 2020. Solutions for humanity on how to conserve insects. *Biological Conservation* **242**: 108427.

Sanchezbayo F and Wyckhuys KA 2019. Worldwide decline of the entomofauna: A review of its drivers. *Biological conservation* **232**: 8-27.

Sandilyan S 2014. Decline in honey bee population in southern India: Role of disposable paper cups. *Journal of Zoological and Bioscience Research* **1**(3): 6-9

Sgolastra F, Blasioli S, Renzi T, Tosi S, Medrzycki P, Molowny-Horas R and Braschi I 2018. Lethal effects of Cr (III) alone and in combination with propiconazole and clothianidin in honey bees. *Chemosphere* **191**: 365-372.

Simon-Delso N, San Martin G, Bruneau E, Minsart LA, Mouret C and Hautier L 2014. Honeybee colony disorder in crop areas: the role of pesticides and viruses. *PloS one* **9**(7):e103073.

Stork NE and Habel JC 2014. Can biodiversity hotspots protect more than tropical forest plants and vertebrates?. *Journal of Biogeography* **41**(3): 421-428.

Taye RR, Deka MK, Rahman A and Bathari M 2017. Effect of electromagnetic radiation of cell phone tower on foraging behaviour of Asiatic honey bee, Apis cerana F.(Hymenoptera: Apidae). *Journal of Entomology and Zoology Studies* **5**: 1527-1529.

Thimmegowda GG, Mullen S, Sottilare K, Sharma A, Mohanta SS, Brockmann, Dhandapany PS and Olsson SB 2020. A field-based quantitative analysis of sublethal effects of air pollution on pollinators. *Proceedings of the National Academy of Sciences* **117**(34): 20653-61.

Tocco C, Foster J, Venter N, Cowie B, Marlin D and Byrne M 2021. Elevated atmospheric CO2 adversely affects a dung beetle's development: Another potential driver of decline in insect numbers?. *Global Change Biology* **27**(19): 4592-600.

Vandersluijs JP, Amaralrogers V, Belzunces LP, Lexmond BV, Bonmatin MFIJ, Chagnon JM, Downs M, Furlan CA, Gibbons L,D Giorio W, Girolami CV, Goulso D, Kreutzweiser DP, Krupke C, Liess M, Long E, McField M, Mineau P, Mitchell EAD, Morrissey CA, Noome DA, Pisa L, Settele J, Simondelso N, Stark JD, Tapparo A, Dyck HV, Praagh JV, Whitehorn PR and Wiemers M 2015. Conclusions of the Worldwide Integrated Assessment on the risks of neonicotinoids and fipronil to biodiversity and ecosystem functioning. *Environmental Science and Pollution Research* **22:** 148-154.

VanEngelsdorp D, Caron D, Hayes J, Underwood R, Henson M, Rennich K, Spleen A, Andree M, Snyder R, Lee K and Roccasecca K 2012. A national survey of managed honey bee 2010–11 winter colony losses in the USA: results from the Bee Informed Partnership. *Journal of Apicultural Research* **51**(1): 115-124.

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Wagner DL, Grames EM, Forister ML, Berenbaum MR and Stopak D 2021. Insect decline in the Anthropocene: Death by a thousand cuts. *Proceedings of the National Academy of Sciences* **118**(2): e2023989118.

Warren R, Price J, Graham E, Forstenhaeusler N and VanDerWal J 2018. The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5 C rather than 2 C. *Science* **360**(6390): 791-795.

Weston DP, Schlenk D, Riar N, Lydy MJ, and Brooks ML 2015. Effects of pyrethroid insecticides in urban runoff on Chinook salmsson, steelhead trout, and their invertebrate prey. *Environmental Toxicology and Chemistry* **34(**3): 649-657.

Williams PH and Osborne JL 2009. Bumblebee vulnerability and conservation world-wide. *Apidologie* **40**(3): 367-387.

Xun E, Zhang Y, Zhao J and Guo J 2018. Heavy metals in nectar modify behaviors of pollinators and nectar robbers: Consequences for plant fitness. *Environmental Pollution* **242**: 1166-1175.