Chapter

Agricultural Intensification Causes Decline in Insect Biodiversity

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Abstract

The world's population exceeded 7 billion in late 2011 and it is expected to reach 9.3 billion by 2050. Meanwhile, demand for food is predicted to increase between 50 and 100% by 2050. To meet the food demands of the increasing population, agricultural intensification practices including growing monocultures of high-yielding crop varieties and increased applications of fertilizers and pesticides have been used to increase productivity. These practices, however, impact negatively on biodiversity of existing flora and fauna, particularly causing huge declines in insect biodiversity. This chapter reviews present state of knowledge about agricultural intensification practices and global decline of insect biodiversity (i.e., pest and beneficial insect species) in intensive agricultural system and point out the likely drivers of these declines. It concludes the review by examining sustainable agricultural intensification practices that could be used to mitigate these biodiversity declines while maintaining productivity in intensive agricultural systems.

Keywords: insect decline, agricultural intensification, crop production, food demands, beneficial arthropods

1. Introduction

Global decline of biodiversity of many terrestrial and aquatic invertebrates, particularly insects, has been a major concern to biologists and ecologists. This is because biodiversity provides many important ecosystem services due their abundance and diversity [1–3]. Much of the decline has been blamed on human activities such as hunting, habitat loss through deforestation, agricultural expansion and intensification, industrialization and urbanization [4, 5], which together accounted for 30–50% encroachment on natural ecosystems at the end of the twentieth century [6]. Agricultural intensification is considered the key driver of this biodiversity loss in many taxa including birds, insectivorous mammals and insects. The removal of natural habitat elements such as hedgerows, trees and other landscape features together with the recurrent use of chemical fertilizers and pesticides in agricultural intensification systems negatively affect overall biodiversity of insects [7]. Extensive use of pesticides is reported as the primary factor responsible for the decline of birds in grasslands [8] and aquatic organisms in streams [9], with probably other factors contributing to or amplifying their effects.

Long-term population monitoring study at several protected areas of Germany revealed a 76% decline in flying insect biomass with an annual loss of 2.8% [10].

Similarly, a study in the rainforests of Puerto Rico showed biomass losses between 98 and 78% for ground-foraging and canopy-dwelling arthropods over a 36-year period, with annual losses between 2.7 and 2.2%, respectively [11]. The authors showed parallel declines in birds, frogs and lizards at the same areas, which they attributed to invertebrate food shortages. The studies above (10–11) confirm the declining trend in flying insects (mainly Diptera) reported earlier for parts of Southern Britain [12]. While climate change may be a contributory factor to arthropod declines, intensification practices including deforestation were reported to be responsible for the annual loss of insect biomass in the tropical rainforest of Germany [10]. The authors also pointed to the effect of synthetic pesticides as a likely driver of the losses in insect biomass.

The above studies demonstrate general knowledge about biodiversity decline in insects. It appears that insect declines are substantially greater than those observed in birds or plants [13], and this could have far reaching consequences on several of the world's ecosystems. This review summarizes current knowledge about insect declines; that is, the changes in species richness (biodiversity) and population abundance through time in intensive agricultural systems point to the likely drivers of these declines and conclude with management practices that could mitigate these declines in sustainable agricultural systems. Previous reviews are limited in scope to one or a few insect taxa (e.g., butterflies, carabids) in specific regions and made no comparisons across taxa in different geographical regions (e.g., Sequera et al. 2014; Zhao et al. 2015).

2. Agricultural intensification production practices

Agricultural production has struggled over the past few centuries to keep pace with the ever-increasing world population of humans, which exceeded 7 billion in late 2011 and is expected to reach 9.3 billion by 2050 [14]. In sub-Saharan Africa, for example, the current population of 1.1 billion people is projected to double over the next 30 years [15]. The increasing population increased demand for food and also brought in its wake increased demand for land for housing, roads and other infrastructural needs, which limited land availability for other purposes including agriculture. Thus, the hitherto traditional agricultural practices such as low-input agriculture with inherent low yields and shifting cultivation appeared no longer tenable in the quest to produce enough food for the growing population. This led to the intensification of agricultural practices more especially after World War II. In Europe and North America, the intensification of agriculture began in the first half of the twentieth century, whereas in South America, Africa and Asia, it started mainly in the second half of the century [16].

The agricultural intensification practices include expansion of farms into large commercial enterprises, accompanied by a changed emphasis to mono-cultures, and the application of increasing inputs of fertilizers and synthetic pesticides [14, 17]. Today's farmlands are larger in scope than their predecessors, more of monocultures, and more rely more on external inputs such as fertilizer, insecticide, and herbicide. In such systems, there is also greater emphasis on the elimination of weeds, cutting down hedgerows and trees in order to facilitate mechanization of fields. Surface waterways are also modified including stream channelization to ease flow and improve irrigation and drainage of fields. These intensification practices drastically reduce the level of refugia available for insects, herbaceous plants, vertebrate insectivores, and other organisms and consequently an overall decline in biodiversity, both in species numbers and in biomass [14, 18, 19].

More than a quarter of the world tropical forests have been cut since the ratification of the Convention on Biological Diversity in 1992, leaving many to wonder whether there will be any substantial stands of tropical forest remaining by the end of this century. Many grasslands and forested areas have also been converted into croplands and plantations [17]. The effects of these practices on biodiversity loss is further exacerbated by the effect climate change, which limit the location of favored regions for crops and other life forms [17].

3. Effects of agricultural intensification practices on arthropod biodiversity decline

A lot has been reported about the effects of agricultural intensification practices on biodiversity loss in insects. Zabel et al. [19] discussed the trade-offs between increasing agricultural intensification and biodiversity decline. Inevitably, increased structural modification of habitats and change in the heterogeneity of farmlands in agricultural intensification systems affect biodiversity. The intensive practices alter the availability of food and shelter for insects and other life forms, which affect the abundance and diversity of species (14). Consequently, major insect declines were observed when agricultural practices shifted from the hitherto low-input traditional farming to the intensive, industrial-scale production brought about by the Green Revolution [19]. In its wake, rare species associated with protected ecosystems and natural habitats retreated or were lost completely [18, 19]. Monocultures led to a great simplification of insect biodiversity among pollinators, insect natural enemies and nutrient recyclers, and created the suitable conditions for agricultural pests to flourish. Thus, agricultural intensification serves as the main driver of insect declines in both terrestrial and aquatic ecosystems [20–22].

Raven and Wagner [17] reported of increased clearing of forests in the tropics for crops, pasture and wood fuel in Central Africa, Central America, many parts of South America and Southeast Asia. An average of 5 million acres of the forest was lost annually to industrial-scale agriculture between 2001 and 2015 [23, 24]. This huge deforestation poses serious threats to the world's insect biodiversity as the majority of insect species diversity is found in the tropics. Deforestation is one of the major drivers of biodiversity loss and insect declines [17–25]. Moreover, deforestation on larger scales has the potential to change weather and rainfall patterns that may further impact negatively on insect populations [24, 25]. Insect biodiversity is very important for successful agriculture in providing many ecosystem services such as pollination, nutrient recycling and biological pest control.

In [26, 27], it was reported that agriculture is the primary contributing factor in insect losses in California and Ohio. According to [27, 28], butterfly diversity in southwest Germany began declining two centuries ago, but with steeper rate of declines observed after World War II, when intensification practices increased. Over the past half century, two-thirds of the common moth species in Great Britain are decreasing in number. Powney et al. [29] analyzed the long-term abundance trends of moths in Great Britain and reported that moth abundances had decreased by 31% over the past five decades [19]. Similarly, in [17], the elevated rate of loss was reported in diverse group of insect fauna of the grassland world, including butterflies and noctuid moths (Lepidoptera); ants, bees and wasps (Hymenoptera); scarab and ground beetles (Coleoptera); crickets, grasshoppers and katydids (Orthoptera); leaf and plant hoppers, seed bugs and their kin (Heteroptera). Further, there are reports of declines of wild bees, particularly from northwestern Europe due to agricultural intensification [30].

4. Biodiversity declines of selected insect groups

This part of the chapter discusses in detail biodiversity declines of selected insect groups caused by the effect of agricultural intensification practices across the globe.

4.1 Lepidoptera

Butterflies and moths have high level of host plant specialization and are therefore vulnerable to habitat deterioration [31]. They also have a wide range of distribution and important for the delivery of key ecosystem services such as biological pest control and pollination [32]. Moths, which are about 10 times more different than butterflies, constitute important prey items for bats and sustain population levels of a myriad of other insectivorous animals [33].

Maes and Van Dyck [34] pioneered report of drastic changes in butterfly biodiversity in Flanders (Belgium) during the twentieth century. They observed that habitat loss due to urbanization and agricultural intensification expansion resulted in a steady decline of 69% of 45 extant species [34]. A follow-up study in the Netherlands by van Dyck [35] also found that 11 out of 20 most common and widespread butterfly species declined in both distribution and abundance between 1992 and 2007. Moreover, local populations of *Lasiommata megera* and *Gonepteryx rhamni* are now endangered and two other species (*Aglais io* and *Thymelicus lineola*) are vulnerable. A parallel study in the Netherland of the range of distribution of 733 species of day-flying moths between 1980 and 2000 showed decline in 85% of species, with 38% critically endangered, 34% vulnerable and 15% threatened [36]. Similarly, a long-term survey at the Kullaberg Nature Reserve in Sweden showed that out of 269 species, 45% declined, 22 were threatened and 159 species were extinct [37]. Monophagous and oligophagous species feeding on grass or herbs in wetlands declined more than those feeding on deciduous trees and shrubs. Also, historical records of 74 butterfly species in Finland showed that 60% of grassland species declined, whereas 86% of generalist species and 56% of those living at forest edge ecotones increased in abundance [38]. For the same locati0n, monitoring the population of 306 noctuid moth species showed drastic declines for species with comparatively longer flight periods and smaller geographical range [39]. Similar findings were reported for northeastern Spain, where in-depth study of the population trend for 66 butterfly species showed a decline in 46 species, while 15 species had increased in abundance and 5 remained stable [40]. A comprehensive report on the status of 576 species of butterflies in Europe found that 71 were threatened and declined over a 25-year period [41]. The greatest declines were observed among specialist butterflies of grassland biotopes (19% species), wetlands and bogs (15%) and woodlands/forests (14%), due to habitat conversion into croplands and intensification of agricultural practices; pesticides negatively affected 80% species. Some species (*Lopinga achine* and *Parnassius apollo*) had declined due to afforestation, that is, conversion of open woodland habitats to dense forests. A recent assessment of 435 butterflies species native to Europe revealed that 19% of the species are declining, while 8.5% species are threatened, and three endangered, *viz. Pieris brassicae wollastoni*, *Triphysa phryne* and *Pseudochazara cingovskii* [42]. A comprehensive database from the UK showed that 41 out of 54 common butterflies species had been declining since the 1970s, with 26% of species showing decreases over 40% of their range [30]. The authors suggested habitat fragmentation and/or destruction and intensification of agriculture, including the increased usage of chemical fertilizer and pesticides, as the possible drivers for this biodiversity loss.

Long-term monitoring data of butterflies are limited in the United States. However, surveys in prairie habitats and bogs of Wisconsin and Iowa showed fluctuating populations of certain species. These fluctuations were driven by habitat modification and moisture levels dependent on climate change [43]. Surveys of 67 butterfly species in California between 1972 and 2012 showed initially stable populations until 1997 when populations dropped steeply to 23 species. The observed declines correlated significantly with percentage of land converted to agriculture and usage of insecticide, with neonicotinoid being the most important. The declining trend in 1997 followed the introduction of the neonicotinoid insecticides in that State [44]. In Massachusetts, the distributional ranges of 116 species shifted northward between 1992 and 2010. Two southern species adapted to warmer conditions expanded in range (*Papilio cresphontes* and *Poanes zabulon*), while populations of 80% of butterflies declined in southern parts of that State [45]. Although survey records are limited, Lepidoptera declines appear to be less dramatic in certain parts of the Asian region. In Japan, 15% of 240 species of butterflies are threatened, with 80% of grassland species being endangered, and two species (*Melitaea scotosia* and *Argynnis nerippe*) close to extinction in the national territory [46]. The steady intensification of Japan's traditional "satoyama" landscape (i.e., a mosaic of rice paddy fields, grassland and coppice forests) has negatively affected most species. In Malaysia, some 19% of moths at Mount Kinabalu (Borneo) had their abundance reduced between 1965 and 2007 (**Table 1**) [47].

4.2 Hymenoptera

Members of this group include bees, ants and wasps. They provide many important ecosystem services such as pollination and biological control of insect pests. Bees are essential pollinators of flowering plants and constitute a third of all pollinators [19]. Also, honey bees have been managed for millennia as a source of honey and beeswax. Hence, a need for information about their population status because of the important ecosystem services they provide [55].

A report on 18 bee species in Britain showed declining trends for seven species since the 1960s. The species with the most declines were *Bombus humilis, B. ruderatus, B. subterraneus* and *B. sylvarum*) [56]. The declines were associated with extensive use of chemical fertilizers as a source of nitrogen [57]. In Denmark, five of 12 native species were extinct, whereas the once common *Bombus distinguendus*

Insect taxon	Declining (%)	Threatened (%)	Extinction rate (%)	Reference
Coleoptera	49	34	6.6	[48]
Diptera	25	0.7	n.a	[49]
Ephemeroptera	37	27	27	[50]
Hemiptera	8	n.a	n.a	[51]
Hymenoptera	46	44	15	[52]
Lepidoptera	53	34	11	[13]
Odonata	37	13	6	[53]
Orthoptera	49	n.a	n.a	[1]
Plecoptera	35	29	19	[54]
Trichoptera	68	63	6.8	[49]

Table 1.
Proportion of declining and threatened species per taxa according to IUCN criteria.

is currently classified as a threatened species [58]. In central Europe, 48 out of 60 species and subspecies have declined over the past 136 years. Of this, 30% are considered as endangered species, while four are extinct [59]. These extinctions are associated with agricultural intensification initiated by the Green Revolution in the second half of the twentieth century [59]. Pollinator declines were reported in Swedish red clover fields since 1940 with only two rare species (*B. terrestris* and *B. lapidaries*) remaining stable [59]. Similar to Denmark, *B. distinguendus* is extinct in the southern part of Sweden, with agricultural expansion and extensive use of agrochemicals reported as the major drivers for biodiversity decline in bees observed over the past 75 years [60]. Similar declining trends were observed among 46% of the *Bombus* species in Europe, of which 24% are endangered and one species (i.e., *B. callumanns*) showing >80% decline due to extensive application of chemical fertilizers in agricultural areas. Further, studies in North America showed that 50% of the 14 bumblebee species in southern Ontario (Canada) were declining. However, three species (*B. bimaculatus, B. impatients* and *B. rufocinctus*) were increasing in abundance, while another three (*B. affinis, B. pensylvanicus* and *B. terricola*) were extinct [61, 62]. In the midwestern regions, a survey on 16 species of bumblebees showed a 50% population decline, while four species (*B. borealis, B. ternarius, B. terricola* and *B. variabilis*) were extinct [18]. A similar decline trend was observed at Itasca State Park (Minnesota), where 11 out of 30 species of stingless bees (Megachilidae) declined, whereas 11 were missing [63–65] due to herbicide use and agricultural intensification.. On a national scale, where historical records were compared with intensive surveys across 382 locations in the USA, 50% of the initial 96% population declined in the last 30 years, and their habitat was condensed to between 23 and 87% [66]. Also in the USA, 3.5 million out of 6.0 million honey bee colonies reported declines, over the past six decades, representing 0.9% loss per year [67]. These declines were linked to the use of dichloro-diphenyl-trichloroethane (DDT) in agriculture [68], toxic pesticides for the management of Varroa mites [69, 70] and poor nutritional value of agro-landscapes dominated by monocultures (e.g., corn, oilseed rape, cotton) [71]. Declines have been reported for bees in Brazil (63%), Costa Rica (60%) and Finland (23%) [72, 73]. Again, these declines were attributed habitat loss due to agricultural intensification practices [74–77]. Other factors contributing to the loss of bees are colony collapse disorder (CCD) caused by pathogens, toxins, parasites and other stressors [58, 78]. Presently, about 40, 30, 29 and 3–13% of colonies are lost annually in USA, Europe, South Africa and China, respectively [55]. The use of pesticides containing neonicotinoids and fipronil is implicated in these losses [58, 78, 79]. These pesticides inhibit the reproductive performances of queens and drones [80, 81], thus compromising the long-term viability of entire colonies [82].

In general, studies [83–85] identified four major phases of bee extinction particularly in Britain. These are as follows: i) the second half of the nineteenth century, with the introduction of guano fertilizers and conversion of arable crops to permanent grasslands, which reduced floral resources; ii) after the First World War, when florally-diverse crop rotations were replaced with chemical fertilizers; iii) between 1930 and 1960, when most species went extinct probably due to changes in agricultural policy (i.e., Green Revolution) that fostered agricultural intensification; and iv) from 1987 to 1994, when rates of decline slowed down perhaps because the most sensitive species were already lost or reduced substantially [20].

Apart from bees, the status of most other hymenopterans (i.e., ants, wasps and parasitoids) that provide important ecosystem services remains practically unknown to date (**Table 2**). There is, therefore, a need for intensive research on these species.

Taxon	Abundance	Decline	Location	Reference
Hymenoptera				
Bumble bees	18 species	7 species	England	[56]
Bumble bees	14 species	8 species	Canada	[61]
Bumble bees	60 species	48 species	Central Europe	[59]
Honey bees	6-m colonies	3.5-m colonies	USA	[67]
Wild bees		52% population	Britain	[85]
Wild bees		67% population	Netherlands	[63]
Wild bees		32% population	North America	[64]
Cuckoo wasps		23% population	Finland	[85]
Stingless bees	30 species	11 species	USA	[64]
Orchid bees	24 species	64% species	Brazil	[72]
Parasitic wasps	48 species	23% species	Finland	[85]
Coleoptera				
Ground beetles	419 species	34% species	Belgium, Denmark	[86]
Ground beetles	49 species	16% species	UK	[87]
Ladybird beetles		68% species	USA	[86]
Dung beetles		31% population	Italy	[88]
Saproxylic beetles	436 species	57% species	Europe	[89]
Odonata				
Dragonflies	52 species	65% population	USA	[90]
Odonata species	200 species	57 species	Japan	[91]
Odonata species	155 species	13 species	South Africa	[92]
Plecoptera				
Stoneflies	14 species	5 species	Czech Republic	[93]
Stoneflies	77 species	29% species	USA	[94]
Ephemeroptera				
Mayflies	107 species	43% species	Czech Republic	[95]

Table 2.
Status of some taxa and their geographical areas.

4.3 Diptera

Hoverflies (Syrphidae) are not only important pollinators, but vital biological pest control agent for pest such as aphids, with a preference for damp habitats. Most studies in the Mediterranean countries showed significant differences in diversity within this taxon, with 249 species alone in Greece [77] and 429 in Spain [96]. This notwithstanding, the only long-term study to date shows reductions in species richness among hoverflies in the Netherlands and the U.K. [76].

4.4 Coleoptera

This insect group contributes greatly to ecosystem management through control of pests and decomposition of organic matter [97]. Habitat destruction, extensive application of toxic chemicals and urbanization are the main causes of their decline.

Of 419 species surveyed in the Netherlands, Belgium, Luxemburg and Denmark, there was a 34% decline for carabids, with over 50% of xerophilic species of the genera *Amara*, *Harpalus* and *Cymindis* and *Carabus* recording a decrease in their populations [98]. Populations of those with large mobility potential remained stable [87]. In the U.K., among 68 carabids at 11 geographical areas, 49 declined, with 26 species considered susceptible and eight threatened, although populations of 19 species remained stable. Generally, 16% of the species were considered extinct throughout the 15-year period of study [99]. There was a 64% species decline in mountainous regions, 31% in moorlands and 28% in pastures. These declines were linked to microclimatic changes and habitat destruction [99]. In a study in New Zealand, 12 species of large carabid beetles were threatened, while another 36 declined with the two genera *Mecodema* and *Megadromus* being the most affected [100].

A study of 62 historical datasets of ladybird species in the USA and Canada showed stable species richness and population abundance [86]. However, a 68% decline was observed over a 20-year period in 1986 [86]. Two local species (i.e., *Adalia bipunctata* and *Coccinella novemnotata*) were classified as extinct in the north-eastern USA [101]. In addition to agricultural intensification and habitat change, competitive displacement by foreign generalist species, such as C. *septempunctata* and *Harmonia axyridis* [102], were identified as potential causes of the decline [103–106]. In the Czech Republic, populations of six species declined, while seven others increased out of 13 species studied [107].

Studies on the trends of dung beetle abundance and distribution are obtainable only for the Mediterranean region, which has the largest range of dung beetles in Europe [108]. A study in Spain indicated that out of the 55 native species, nine had declined from 28 to 7% loss, while their distributional range contracted from 48 to 29% [108]. *Scarabaeus pius* and *Gymnopleurus mopsus* were the most threatened species. Multivariate analyses showed that commercial farming, urbanization, and extensive use of pesticides were responsible for the declines [108]. Further, a study in Italy showed 31% decline in roller dung beetles and nine were extinct [88]. The trend of decline commenced from 1960s (two species), increased in the 1970s (three species), and peaked in the 1980s (six species). The possible primary decline factors were conversion of pastures to forests, agricultural intensification and a shift from free-ranging to stalled livestock management that reduced dung availability to foraging beetles.

Studies of scarab beetles showed that two *Scarabaeus* and four *Gymnopleurus* species are threatened, while *G. mopsus* is probably extinct [109, 110]. In France, a survey of the coastal region of France in 1996 showed nine Scarabaeidae were threatened and two Aphidiidae declined while Geotrupidae were extinct [111]. An earlier study showed 45-fold decline of *Scarabaeus semipunctatus* [89, 112]. In Europe, a study on saproxylic beetles showed that deforestation, agricultural intensification and wood harvesting caused destruction of native forests, thus endangering the survival of 56 beetle species. The two species, *Glaphyra bassetti* (Cerambycinae) and *Propomacruscypriacus* (Euchiridae), were the most threatened [109]. Since the abundance and distribution of 57% of the 436 known species are unidentified, the number of declining species could be even higher [113].

4.5 Hemiptera

These are distinctive phytophagous insects of plane regions, associated with natural and anthropogenic grasslands areas [85]. Sweep-net samples collected from 1963 to 1967 were compared with those collected from 2008 to 2010 at the same sites regarding species diversity, species composition and abundance. Generally, there was no change in species richness, irrespective of the strong interannual variability in abundance and weather condition. However, a decline in 14 species was observed while there was an increase in nine others and one species (*Zyginidia scutellaris*) increased in abundance and distribution. Median abundance decreased by 66% (from 679 to 231 individuals per site) over the 47-year period [114, 115]. The primary cause factors were attributed to airborne and soil acidification, partly due to agricultural intensification.

4.6 Orthoptera

A wide-ranging study on grasshoppers and crickets was conducted in Germany [116]. There was no fluctuation in their biodiversity and abundance over four decades (median nine species per site), and variations in species groupings were small. The only significant change was a steep decline in the Grasshopper of bare soils, *Myrmeleotettix maculatus*, while there was an increase in two generalist cricket species, *Tettigonia viridissima* and *Phaneroptera falcate*. Contrasting with other taxa, few Orthoptera species exhibited noticeable decline trends, possibly because most species are highly adaptable polyphagous grazers. Nonetheless, about half of the species are considered threatened in Germany.

4.7 Odonata

Dragonflies (Anisoptera) and damselflies (Zygoptera) are a small group of insects that contribute to the management of nuisance mosquitoes and agricultural pests [117, 118]. Of 118 aquatic insect species that are threatened, 106 are from the order Odonata [94, 119]. A study of 42 sites across USA recorded a decline in 52 species of dragonflies and damselflies, while there was an increase in 29 species over the 98-year period. Nine pollution-tolerant species declined significantly, including four species (*Sympetrum danae*, *Sympetrum costiferum*, *Ophiogomphus occidentis* and *Libellula nodisticta*) that were in an earlier survey [90]. In Europe, 15% of 138 Odonata species are currently endangered, with two damselflies (*Ceriagrion georgifreyi* and *Pyrrhosoma elisabethae*) and one dragonfly (*Cordulegaster helladica* sp. kastalia) highly threatened with extinction. Major declines for these insects occurred through the post-1960 agricultural intensification, with pollution of irrigation water by urban runoff and extensive application of agrochemicals being major causes [120]. In Japan, 57 out of 200 Odonata species are declining while 19 are threatened [91]. The greatest losses of populations are among lentic species once common in rice paddy fields, with the red dragonflies (*Sympetrum* spp.) experiencing the sharpest decline since the mid-1990s [121]. This decline has been associated with the use of fipronil and neonicotinoid insecticides [122, 123]. Similarly, of the 155 Odonata species recorded in South Africa, 13 are declining, while four others are extinct [92]. The authors opined that fortification of rare species in natural reserves of the country does not guarantee their survival, as current livestock management and other human activities negatively impact on their population.

4.8 Freshwater taxa

Freshwater insect taxa mostly exhibit inflexible life cycles, with several species being univoltine, thus making them vulnerable to habitat modifications. Flow changes, habitat fragmentation, pollution and invasive species are the main threats to all aquatic organisms, including insects [124, 125]. Data for three main orders of freshwater insects, Plecoptera, Ephemeroptera and Trichoptera, are reported here. There were no records found for Coleoptera (e.g., Dytiscidae, Hydrophilidae), Hemiptera (e.g., Notonectidae, Gerridae) or Diptera (e.g., Chironomidae, Tipulidae).

4.8.1 Plecoptera

Stoneflies are ecologically important and characterized by high degrees of endemism and narrow ecological requirements [126]. Previous report in Europe showed a disappearance of *Aeniopteryx araneoides* and *Oemopteryx loewi* over the entire continent, while *Isogenus nubecula* was locally extinct [127]. The level of extinction ranges from 50% in Switzerland to 13–16% in the Mediterranean countries such as Spain and Italy. Up to 63% of the 516 European species of stoneflies are vulnerable to habitat destruction and climate change [128]. Stoneflies are susceptible to variation in water flow, even though they show resistance to acidification as compared with other macro-invertebrates [129]. A study of 78 stonefly species at 170 sites in the Czech Republic reported that low- and mid-altitude streams accounted for three quarters of the changes in species diversity. This was mainly due to pollution, impoundment and channelization at those sites [130]. Lowland river habitats indicated five endangered species of the 14 native species documented in the nineteenth century, while four were considered extinct. Over a 50-year period, 12% of the species disappeared, whereas two new species (*Brachyptera monilicornis* and *Leuctra geniculata*) appeared. Moreover, 22% of species reported had declined by >50%, including common species such as *Perla abdominalis, Amphinemura standfussi* and *Nemurella pictetii,* while a further 10% had become vulnerable.

Unlike terrestrial taxa, most declines were found among habitat generalists and less in specialized species (60–70%), which are tolerant to organic pollution. Sites affected by organic pollution showed only 17–33% decline of subtle and eurytopic species since the mid-1990s [93]; certain amount of species recovery has been detected following pollution modification in acidified habitats [131]. In Switzerland, 50% of the species of stoneflies and mayflies were lost between 1940s and 1980s [132], and similar trend occurred in other European countries and the USA, where 29% of the 77 local stonefly species were lost and 62% of the remainder became endangered over the past century [94]. Main losses occurred in the large rivers and agricultural areas during the 1940s and 1950s, when both agricultural intensification and urban expansion took place. Modification of river flows, channels and drainages structures was considered the driving factors for the declines. The large, long-lived species of Perlidae (summer stones) and Perlodidae (spring stones) were impacted the most, and 36% of summer stones had gone extinct since 1860. For sensitive genera such as *Acroneuria*, 88% of populations in the entire contingent were lost over the past century, whereas genera tolerant to organic pollution such as *Perlesta* had increased fourfold.

4.8.2 Ephemeroptera

A checklist of mayfly species in the Czech Republic identified 107 species of which four are considered extinct, seven critically threatened, another seven endangered, 16 vulnerable and 14 near threatened [95]. A comparison of local mayfly also showed variations in species abundance, distribution and composition, but no major declines were observed in biodiversity except for the large lowland rivers, which lost five specialist species [133]. Biodiversity improved slightly in the mid- and upper streams and rivers, possibly because of substantial reduction in water pollution post-1989 [93]. Two species became extinct (*Isonychia ignota* and *Ephemerella mesoleuca*), three became very rare, 11 were declining and nine were expanding their range, including the dominant *Centroptilum luteolum* and *Baetis* *niger* [93]. Main variations were due to losses of previously common and widespread species such as *B. alpinus* and *Epeorus assimilis*. The general difference among sites (15–30%) was mainly driven by species replacement. The present communities have shifted toward more simplified and less specialized assemblages in large rivers, whereas mayflies in small creeks have been replaced with species tolerant to pollution and siltation [93, 133]. In North America, a total of 672 species of mayflies are listed though no details are available about their abundance and distribution [134]. A collection for North and South Carolina (USA) reported 204 species [135], but again no status was indicated. A later study in relation to 10 rare species revealed, however, that four of the species sampled in the early twentieth century should be considered extinct [136].

4.8.3 Trichoptera

A comprehensive study on caddiflies species recorded 278 species in comparatively uninterrupted regions of Minnesota (USA) since the 1890s. Among the 278 species, 6–37% have declined in different areas, especially within the Limnephilidae (44% of species), Phryganeidae (21%) and Leptoceridae (12%) families [137]. *Agrypnia glacialis* and *Anabolia sordida* are presently considered extinct, whereas 17 rare species are yet to be found since the 1950s [137]. Entirely affected species are either in the univoltine or in the semivoltine family and because of their long life span and feeding habits, are mainly susceptible to anthropogenic disturbances in water courses. The majority of losses are found among shredder (72%) and predatory species (11%), which agrees well with losses of aquatic taxa in other countries [138, 139].

5. Sustainable agricultural intensification practices to mitigate biodiversity declines

The reports above show clearly that although agricultural intensification practices improve yields, they also impact negatively on the environment as evidenced by the decline in insect biodiversity. Biodiversity is an integral part of the natural resource base for agricultural production and therefore must be protected to sustain and safeguard the increased yields for the present and future generations. Over time, plant productivity decreases as biodiversity is lost [14]. A large proportion of studies (49.7%) point to habitat change as the main driver of insect declines, a factor equally implicated in global bird and mammal declines [135, 136]. Thus, habitat management practices are a key for sustainability of agricultural intensification practices. According to [136, 137], sustainable agricultural intensification is the management and conservation of the natural resource base and the orientation of technological and institutional change to ensure the attainment and continued satisfaction of human needs for present and future generations. It involves a process to produce high yields for existing land resource without affecting the environment. Sustainable intensification must include natural resource management practices that maintain the diversity of habitats as an intrinsic part of the agro-ecosystem or as additional land use interspersed among the fields (Firbank et al. 2008). These practices include crop rotation, reduced tillage, soil and water conservation, application of organic manure, intercropping and agroforestry [136, 138]. The practices will among other benefits ensure sustainable soil fertility through improved soil structure and soil microbial activities. Thus, sustainability requires the integration of multiple practices on a long-term basis to achieve desired environmental and agricultural outcomes. Intercropping with improved cultivars as well as integration of mixed crops with agroforestry and livestock could promote sustainable intensification and food security [137]. Also, the judicious implementation of integrated pest management (IPM) will minimize the use of toxic pesticides and enhance environmental safety for sustainable crop production [138]. Furthermore, in many of the world's farming systems, biological control constitutes an under-utilized and yet cost-effective tactic for pest control. The effect of biological control will be felt more in sustainable intensification systems such as those that involve IPM practices that are benign to natural enemies of pests and/or conserve biodiversity [139]. For aquatic insects, rehabilitation of marshlands and improved water quality are essential for biodiversity conservation and enhancement [140]. This may require the implementation of effective remediation technologies to clean the existing polluted waters [141, 142].

6. Conclusions

This chapter has provided a comprehensive discussion of effects of agricultural intensification on decline in insect biodiversity. Intensification practices highlighted as causes of this decline include expansion of farms into large commercial enterprises, cutting down hedgerows and trees in order to facilitate mechanization of farms, changed emphasis to monocultures, and increasing application of external input of fertilizers and synthetic pesticides. These practices largely reduce the level of refugia available for insects, herbaceous plants, vertebrate insectivores, and other organisms and consequently an overall decline in biodiversity, both in species numbers and in biomass. Insect biodiversity is integral to the resource base of the plant ecosystem that provides essential services for increased crop productivity and, therefore, must be protected to safeguard the survival of the present and future generations. To mitigate this decline therefore, the chapter highlights sustainable intensification practices to include habitat restoration practices such as intercropping, crop rotation, reduced tillage, agroforestry, application of organic manures coupled with drastic reductions in application of synthetic pesticides.

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Conflict of interest

The authors declare no conflict of interest in the publication of this book chapter.

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