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Scientific Advisory Board on Biodiversity and Genetic Resources at the Federal Ministry of Food and Agriculture

For an efficient and area-effective insect protection

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Imprint

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Summary

Insects are essential components of ecosystems. Among other things, they decompose organic matter, pollinate a large part of plants and serve as food for many other animals. They thus generate many services, such as pollination of crops or biological pest control, which we use every day and on which we depend. The currently available data indicate a serious loss of this most species-rich animal class, both in terms of species numbers as well as with regard to population sizes. Due to close ecosystem links, this loss also has a direct impact on the population development of other animal and plant species as well as on the condition of ecosystems in general. The decline is the result of complex, often cumulative influencing factors, whereby the widespread and increasing impoverishment of landscape structures as well as the input of nutrients and pesticides plays an essential role.

The quality and quantity of the loss of insects is an expression of an impoverishing landscape and a warning signal of a further substantial loss of biodiversity. Immediate action is therefore required. Consequently, the German government has agreed to develop an "Insect Protection Action Programme" and has already presented the key points for this. In order to slow down the loss of insects and to stop it in the medium term, far-reaching, systemic and widespread, area-effective approaches are necessary, which require various complementary measures. Agriculture plays an important role due to its input of substances into soils, water and air and because it affects a large area. In this regard, the most important measures are the reduction of inputs of pesticides and nutrients as well as the substantial enrichment of monotonous landscapes with small structural elements such as hedges, trees and field margins as well as the protection and sustainable use of extensive grassland.

The current reform of the EU's Common Agricultural Policy is an important window of opportunity that should be used urgently to strengthen the promotion of biodiversity in agriculture and adequately reward corresponding measures. In addition, there are measures to be taken in residential areas. Here, the application of pesticides must also be drastically reduced – both on public green spaces as well as on private areas. Preliminary evidence suggests that reducing light pollution could also make a significant contribution. People's awareness of the great diversity of insects and their functions beyond pollination should be improved and the contribution that citizens can make to their conservation should be more strongly communicated. In order to record the population trends of insects, the Federal Government should design a nationwide monitoring system together with the federal states and start establishing it before the end of the current legislative period. A national centre for biodiversity monitoring should integrate this with other monitoring activities and be jointly supported by authorities, science and civil society.

A further loss of insects and thus of fundamental ecosystem services would have far-reaching negative consequences, not only for this evolutionary extremely old and most of its long existence very successful animal class itself, but also for human welfare and the environment.

1 Introduction

1. Insects represent the largest and most species-rich class of the animal kingdom. In the course of their evolution, they have developed an incomparable diversity of lifestyles and survival strategies and have adapted to a wide variety of habitats. Thus, they have become essential components of ecosystems and form an essential part of their foundation: they pollinate a large part of plants and contribute to their distribution and reproduction. Insects themselves provide food for many other animals and act as predators and parasites in regulatory processes. By decomposing organic material, they promote soil fertility and facilitate nutrient cycling. These services are largely unnoticed by humans and are taken for granted. Ecosystems, and with them humankind, are directly and indirectly dependent on insects for their diverse services. At the same time, however, some insects can also transmit diseases to humans and animals or impair crops, food supplies or goods. They are therefore often seen as pests and many people reject them. However, despite their adaptability to a wide variety of habitats and although the number of insects seems almost infinite (the number of species in their class exceeds by far that of other animal groups), their population sizes have already fallen significantly and are continuing to decline (paragraph 10ff).

2. For some time now, experts have been observing a decrease in the abundance and diversity of insect species. The overall extent of this creeping, continuous but accelerating decline in many species groups is only now becoming apparent. Surprising in its extent even for many experts, this loss across species has recently become obvious in a long-term study by the Entomologischer Verein Krefeld e.V. (HALLMANN et al. 2017). The study revealed a striking decrease in the biomass (total weight) of flying insects by up to 80% in midsummer in several German protected areas over the past 27 years (see paragraph 13). Nationwide Red Lists and studies at European and international level underscore this long-term downward trend (chapter 2). From both an ecological as well as an economic point of view, the dimensions of the loss are extremely worrying. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) summarises these developments at a global level in its report on pollinators and food production and emphasises humankind‘s strong dependence on insect performance (IPBES 2016).

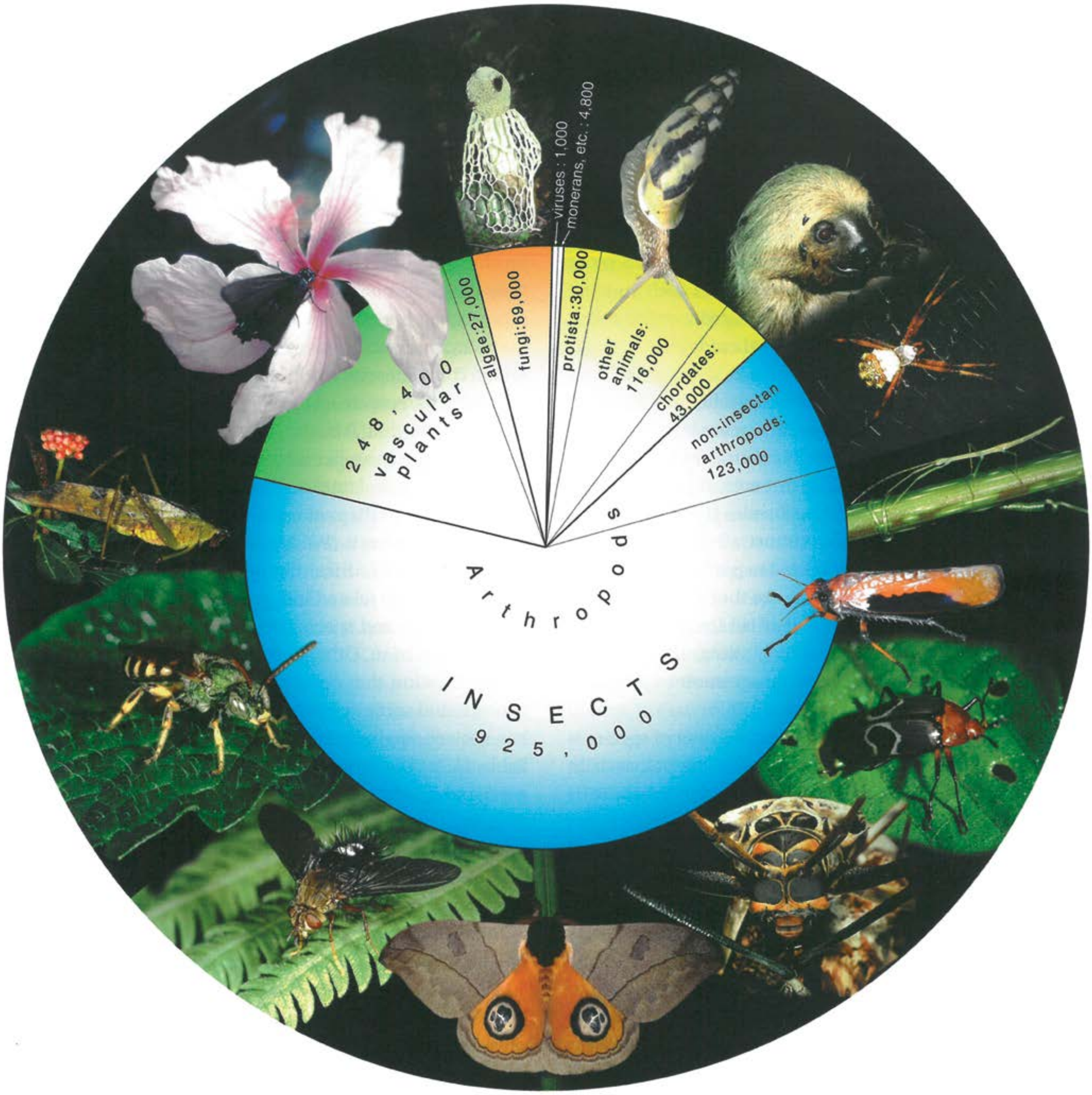
3. The decline of insects and biodiversity as a whole are closely interlinked: on the one hand, the insect species which have so far been described, account for the largest proportion of the world’s organism groups (Fig. 1) and the global loss of biodiversity is therefore primarily an insect loss in terms of quantity. In Germany too, around three quarters of all animal species are insects (German government 2018). On the other hand, insects play an important role in the stability of food webs due to their ecosystem functions. Their loss, therefore, also has a direct impact on the population development of other animal and plant species as well as on the condition of ecosystems in general. It is thus the starting point for further ecological hazards. Finally, major causes of the decline of insects are also relevant for the loss of other species. The increasing disappearance of insects, as well as other species especially of the agricultural landscape is therefore to be seen as an urgent warning signal: it is the concomitant phenomenon of a general landscape impoverishment resulting from large-scale intensive land use (chapter 3). This is reflected in particular in the decline of the quantity and quality of remaining terrestrial and aquatic habitats due to substance inputs, homogenisation of the landscape, and its fragmentation. In addition, there are other factors such as climate change and the increase in artificial light sources that also have an impact. Taken together, the insect loss is a systemic and widespread problem that must be addressed by a comprehensive package of measures.

4. For some years now, the topic of “insect deaths” has also been increasingly present in the public. Initially, the focus was mainly on the popular honey bee (*Apis mellifera*). However, this is to a certain extent a special case, as its population is not declining due to breeding despite high mortality in Germany. Furthermore, as a domesticated animal, the honey bee is entirely dependent on humans. However, it is by far not the only pollinating insect, even though pollination is often first associated with the honey bee in the general public (see paragraph 19). The debate on the overall decline of insects has gradually expanded – also in public discussion. Possible reasons for this are the general attention which resulted from the study of the Krefeld entomologists as well as an increasing subjective perception that formerly ubiquitous insects become fewer.

By now, the issue has attracted a great deal of political attention. This is also reflected in the “Insect Protection Action Programme” agreed upon in the coalition agreement of the federal government and launched by the federal cabinet on 20 June 2018 as a white paper (Federal Government 2018). Increasingly, insect protection

○ Figure 1

Species richness of different groups of organisms so far described worldwide



Glossary: Arthropods (the root of the animal kingdom consisting of insects, arachnids, crustaceans, millipedes, et al.); vascular plants; algae; fungi; viruses; monerans prokaryots (bacteria, cyanobacteria, archaebacteria); protista (unicellular and unicellular-colonial eukaryotes, i.e. algae, some fungi, protozoa); chordates (tunicates, cephalochordata, vertebrates, i.e. incl. mammals and human beings)

Source: GRIMALDI and ENGEL 2005, P. 3

measures are also being introduced in other countries and at EU level. In June 2018, the European Commission presented the first EU-wide initiative for the protection of pollinating insects, with short-term measures until 2020 and a long-term perspective until 2030 ("Pollinating insects: Commission proposes actions to stop their decline", press release of the European Commission of 1 June 2018). At the international level, the "Coalition of the Willing on Pollinators" was founded in 2016 on the basis of the IPBES report on pollinators. Germany is currently one of the 21 signatory states (Promote Pollinators 2018).

5. The scientific knowledge available to date on the extent and the anthropogenic causes of insect decline (see chapters 2 and 3) highlights an urgent need for action. Although the state of knowledge about the ecology and needs of the individual insect species needs to be further developed, it is neither necessary nor justifiable to wait for further findings as a prerequisite for additional measures against the background of the rapid population losses. The decline of insects must immediately be slowed down and stopped in the medium term, not least because of their central functions for entire ecosystems, and thus also for people. Even where not all factors can yet be proven with absolute certainty to cause the decline, the precautionary principle as a guideline for German environmental policy requires action. Especially if, as is the case here, the effects are severe and potentially irreversible. The Federal Act for the Protection of Nature (Sec. 1 of the BNatSchG) and the Convention on Biological Diversity (CBD) of 1992 also require the federal government to stop the loss of biodiversity (and therefore also of insects). In both documents, the intrinsic value of biological diversity is mentioned first. Moreover, the EU Nature Directives – Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitat directive) and Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (Birds Directive) – require Germany to protect valuable (insect-) species in the FFH habitat types, respectively, to conserve the nutritional basis for insectivorous birds. In accordance with the Water Framework Directive 2000/60/EC, the status of macrozoobenthos as one of the biological quality components must at least be rated as "good" in order for the water body to achieve a "good ecological status". The macrozoobenthos are invertebrates, living in the beds of running waters and visible to the naked eye, including insects.

Substantial countermeasures of an insect protection action plan must address the already mentioned causes of insect loss of and must be effective on a large scale. This means that the measures go beyond spatial and temporal single measures and thus achieve a positive effect on insects in the wider area. In general, the currently increasing problem awareness should also be taken as an opportunity to address biodiversity conservation more strongly than before and to combine it with its positive effects on society at large (cf. Naturkapital Deutschland – TEEB DE 2016).

2 Insects and their importance for nature and humans

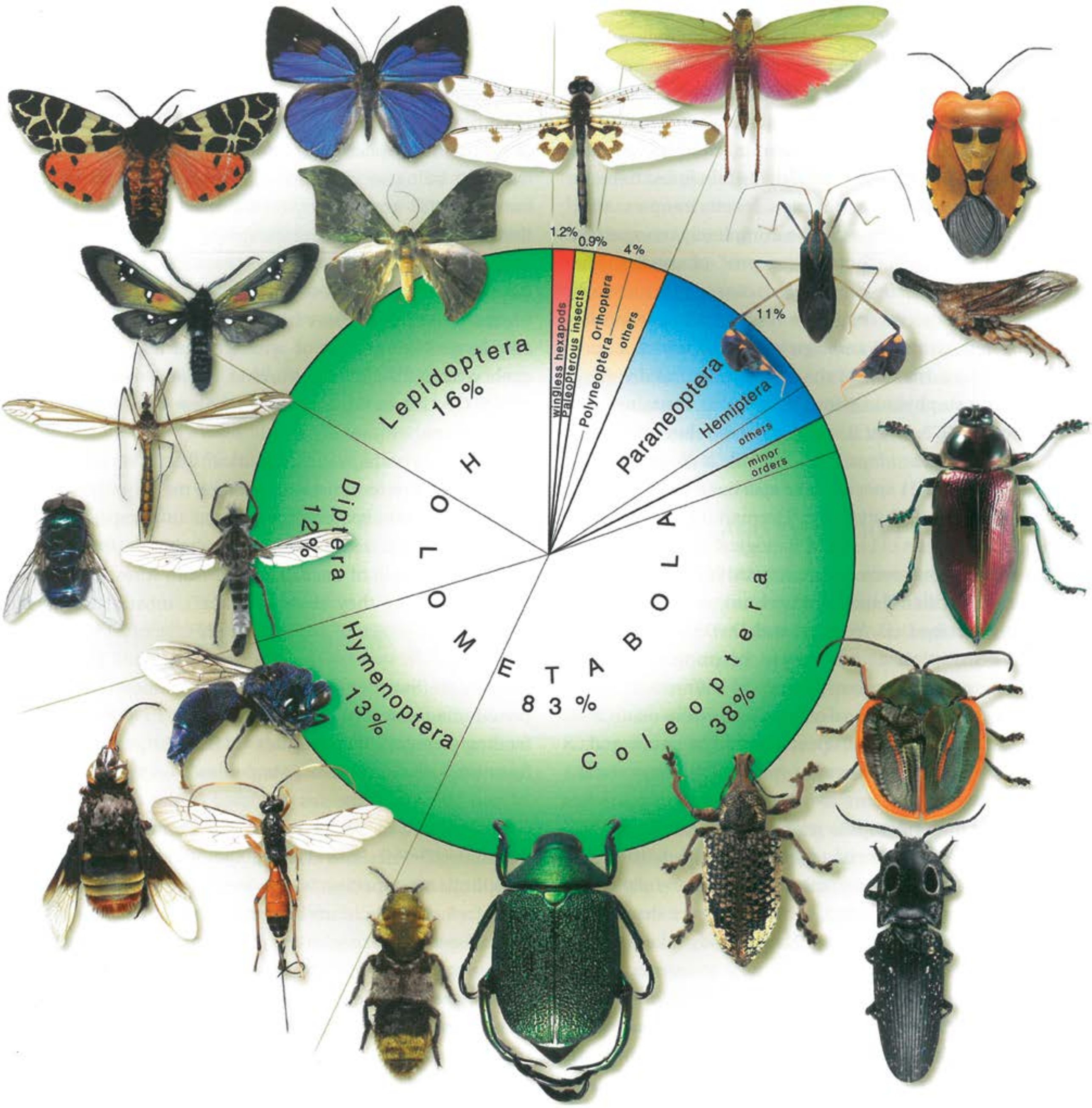
The diversity of insects

6. The class of insects is the most diverse and species-rich in the history of life on Earth. Common to all insects is a division of the body into three sections (head, thorax, abdomen). They have six legs, an exoskeleton and, during their development from egg to imago (adult insect), generally pass through several larval stages. Depending on the species, this larval stage can take place in a completely different habitat than the adult phase and can account for a large part of the life span. During their metamorphosis, most insects have an additional pupae stage and are therefore referred to as holometabolic. Hemimetabolic insects do not have this stage of development. The class of insects includes, among others, the four extremely diverse orders of beetles (coleoptera), butterflies (lepidoptera), hymenoptera (e.g. wasps, bees, ants) and diptera (e.g. flies). These four orders alone cover a total of 80 % of all insect species worldwide (GRIMALDI and ENGEL 2005). In addition, there are dragonflies, orthoptera, bugs, fleas and cockroaches, as well as numerous other orders (see Fig. 2).

7. Insects stand out in many ways from all other groups in the animal kingdom. During the course of evolution, they have adapted to almost all, even extreme, habitats through the development of various forms and survival strategies. Only in oceans few insect species exist. Concerning their diversity, however, one can only guess: So far, about one million insect species have been described worldwide, but estimates range from a total of 2.5 to 10 million species. In contrast, the number of almost completely assessed mammal species worldwide is 5,488 (IUCN 2017). The extremely diverse group of insects, with their large number of species, is also reflected in the

Figure 2

Taxonomic orders of insects worldwide



Glossary: Holometabola – insects with metamorphosis through a pupal stage; Lepidoptera – butterflies; Diptera – dipterans; Hymenoptera – hymenopterans; Coleoptera – beetles; Paraneoptera – e.g. psocoptera, lice, thrips; Hemiptera – true bugs; Polyneoptera – e.g. locusts; Orthoptera – grasshoppers; Paleopterous insects – e.g. dragonflies or mayflies which cannot lay their wings over the abdomen; wingless hexapods

Source: GRIMALDI and ENGEL 2005, P. 13

diversity of lifestyles and habitat requirements. For example, ground-based beetle species from the ground beetle or weevil families are influenced by entirely different factors than flower-visiting butterflies or dragonflies with aquatic larval stages. Many species have multiple habitat requirements, for example with regard to food intake, egg deposition, or hibernation, and therefore require a variety of measures for their protection. How different the lifestyles of insects can be is illustrated below by two examples.

Examples of the diversity of lifestyles and habitat requirements of insects:

Figure 3

Dusky large blue (*Maculinea nausithous*)

Photo: André Künzelmann,
Helmholtz Centre for Environmental Research (UFZ)

8. The dusky large blue (Fig. 3) is a highly specialised butterfly closely linked to the occurrence of both a plant species (great burnet – *Sanguisorba officinalis*) and an ant species (European fire ant – *Myrmica rubra* or a few closely related species). These conditions are mainly found in wet, extensively used meadows and pastures, young brownfields, or along watercourses. This species is particularly threatened by intensification of cultivation or abandonment of use. The intensification of cultivation leads to more frequent mowing and increased nutrient input, but most flowering plants and insects require nutrient-poor levels. In contrast, abandonment of use leads to fallow land with unhindered growth of trees and bushes (shrubbery). This leads to increasing shading and thus decreasing surface temperatures as well as to fewer flowering plants. The adult butterflies live only for a few days. They lay their eggs on the flowers of the meadow button (*Sanguisorba*) and the caterpillars initially feed on the flowers and fruit of the plant. After a few weeks, the caterpillars let themselves fall from the flowers and are carried by the European fire ants into their anthill. At this time, the caterpillars change from a plant-based to an animal-based diet and feed on ant larvae. In order to avoid being eaten by the ants, the butterfly caterpillars imitate the scent of the anthill and discharge a sugar-containing secretion which is taken up by the ants. Thus the caterpillar is cared for by the ants and hibernates under the protection of the anthill. When the adult butterfly hatches out of the pupa, it loses its chemical camouflage and quickly leaves the anthill.

Figure 4

Broad-bodied Chaser (*Libellula depressa*)

Photo: Tim Bekaert

9. The broad-bodied Chaser (Fig. 4) is a widespread and common dragonfly species in Germany. The adult animals are excellent and fast flyers, which can also cover greater distances and feed on other insects, which are caught in flight. Their lifespan generally ranges from one to two months. The males are blue and the females yellow. The females lay their eggs in flight in small, stagnant waters such as natural puddles, pools and ponds. There, the larvae usually develop within one to two years, and moult up to 14 times. Buried in mud, they can also survive periods of drought or the freezing of the water. They are also predators and predominantly feed on aquatic insects. They are often the first colonisers of new habitats, which is related to the original habitat of this species – puddles that form in natural floodplains during floods.

Population developments

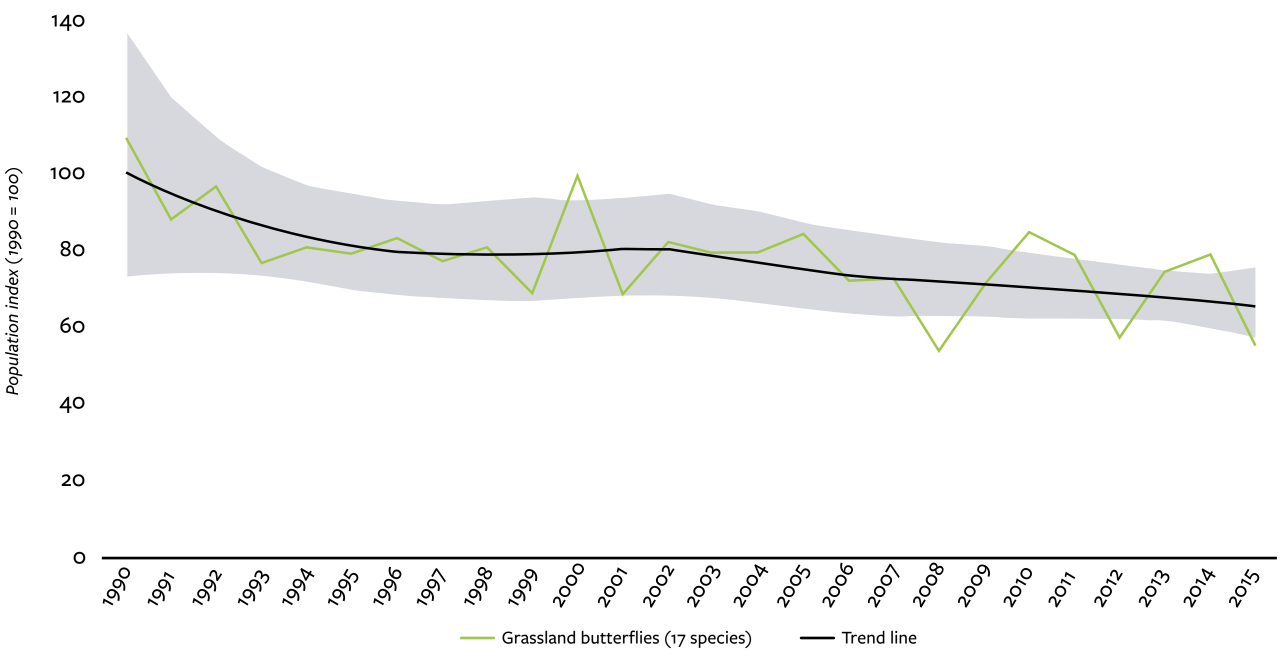
10. With their emergence at least 400 million years ago, insects have existed for an extremely long time compared to other animal classes. Although they are considered to be evolutionarily the most successful animal group, many species are now threatened. The dramatic loss of population sizes and species numbers of insect could even be disproportionately high compared to other taxonomic groups (BROOKS et al. 2012; RÉGNIER et al. 2015; THOMAS et al. 2004). However, not least because of their great diversity, only a few insect species have to date been studied in detail (SCHOWALTER 2016). It is therefore possible, that the worldwide loss of insect species is still underestimated (RÉGNIER et al. 2015; THOMAS et al. 2004).

The level of knowledge about the individual insect species therefore differs considerably. While some species groups are largely unexplored, there is for example a comparatively good data basis for butterflies (MERCKX et al. 2013). They represent one of the most intensively studied insects orders (THOMAS 2016). This presumably results from their general (historical) popularity, as well as being comparatively simple to study, since they are visually easy to notice and identify. Based on extensive, long-term data sets, well-founded statements on changes in the distribution and population sizes of butterflies can be made (THOMAS 2016; MERCKX et al. 2013; THOMAS et al. 2004). The losses at both, the species and individual level, are serious (THOMAS et al. 2004; MERCKX et al. 2013; WENZEL et al. 2006). For example, the number of butterfly species in southern Germany decreased from 117 species in 1840 to 71 species in 2013 (HABEL et al. 2016). The “European Grassland Butterfly Indicator”, a status indicator of the EU biodiversity strategy, examines the development of 17 grassland butterfly species in 19 European countries as representative of all local butterfly species (Fig. 5). Between 1990 and 2015, there was a general reduction of 30% in their populations in Europe (van SWAAY et al. 2016), with for some species the losses being much higher.

11. These findings are of overriding relevance in so far as butterflies are regarded as indicator species for the state of biodiversity and ecosystems. Although their population sizes cannot mirror the highly diverse class of insects as a whole, butterflies exhibit patterns of species’ diversity and endemism (i.e. the occurrence of one species restricted to a defined area), that are representative of other insect groups. They are therefore increasingly used in Europe and elsewhere as indicators of population changes in other insect groups (MERCKX et al. 2013; EEA 2013; WENZEL et al. 2006; THOMAS et al. 2004). For other groups such as bumblebees, dragonflies, and ladybirds comparable trends with population losses are known. In some cases, the decrease in other groups still exceeds that of butterflies (THOMAS 2016; THOMAS et al. 2004; DIRZO et al. 2014). For example, in a British study conducted between 1994 and 2008, three quarters of the beetle species studied experienced significant population decreases, half of which were affected by a reduction of more than 30% (BROOKS et al. 2012). The negative population development of many insect species is also documented by the Red Lists of invertebrates published by the Federal Agency for Nature Conservation (BfN) with representative data for the entire territory of Germany. Of the 557 bee species evaluated in Germany, almost 50% are classified as extinct or endangered, and the same applies to 52.8% of ant species.

Figure 5

Grassland butterfly index trend in the EU



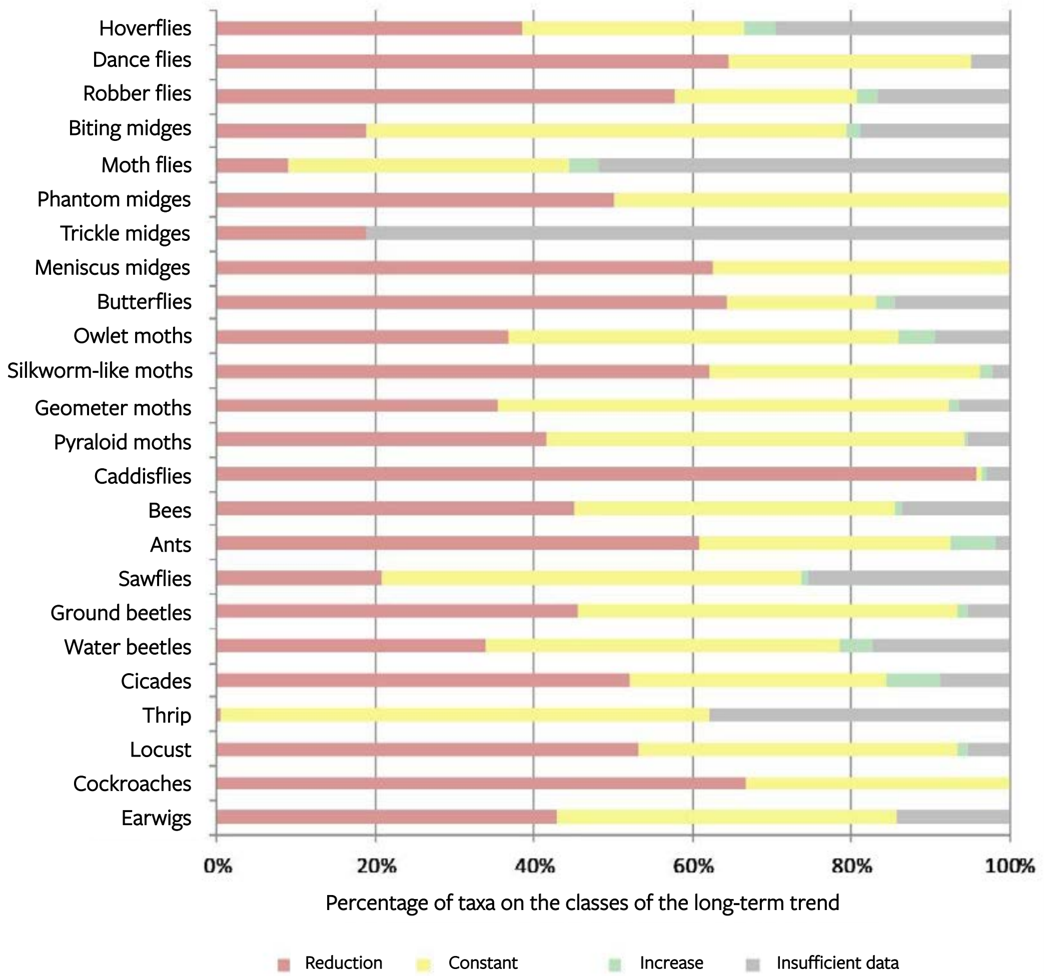
Source: EEA 2018b

The German national Red Lists are characterized by the fact that they consider both the current (preferably new data up to max. 25 years old data), the short-term (last 10 to max. 25 years old data) and the long-term (50 to 150 years old data) population trends and classify the species into the categories "decline", "constant" and "increase". Nearly 92% of the ant species show short-term declines in population. In the case of caddis flies, even 96% of species are declining in the long-term trend (Fig. 6). Overall, 45% of the insect species examined for the Red List show a declining population trend, only 2% of the species show population increases. The latter may be related, among other things, to the development of new habitats, but also to improved data availability and thus not to improvements in conservation status (BfN 2011).

12. The described losses are not a new phenomenon, but have already been observed for many decades and thus, go beyond natural population fluctuations. Results from long-term studies of butterflies in Germany and the Belgian region of Flanders also show that species loss has increased significantly since the second half of the 20th century, especially since the 1970s (HABEL et al. 2016; WENZEL et al. 2006; MAES and VAN DYCK 2001). A strong acceleration of the decline has also been observed for ant species (BfN 2011). In contrast, the analysis of historical data sets (1851–1994) on the extinction of bees and flower-visiting wasp species in Great Britain showed that the extinction of species has slowed down since the middle of the 20th century (OLLERTON et al. 2014). The authors of the study cite more effective protection measures and/

Figure 6

Long-term population development trend of Red List insect species in Germany*



* Right-hand column: number of taxa (species, subspecies, local forms or species complexes) for species group. Invasive species, unevaluated taxa and extinct taxa are excluded. The Red List for wasps was not included in the assessment. The 'decline' category includes the classes of very high, high, and moderate declines, as well as extent of decline unknown.

Source: BfN 2018a

or the loss of more sensitive species that has already occurred as possible causes.

13. The so-called Krefeld study based on data from the Entomologischer Verein Krefeld e.V. [Entomological Association], published in October 2017, attracted particular attention in politics and society (HALLMANN et al. 2017). Using special traps for flying insects (Malaise-traps), the insect biomass (total weight) was studied in 63 protected areas of individual German federal states over a period of 27 years. The study documented a reduction of more than 75% in the total weight of insects caught, up to 82% in July and August and between 1989 and 2016. It has to be taken into account that the results cannot generally be transferred to other areas with other forms of land use. Furthermore, the study design offers only general statements about the development and gives no analysis of possible causes. It should also be noted that insect species are differently attracted to Malaise-traps, the locations of the traps varied, and that a different starting point of the study would have shown a different decrease due to natural inter-annual population fluctuations. However, this is not a negative aspect unique to this study. The reference to the total insect biomass that is not differentiated by species still makes it possible to estimate the dramatic development in the total occurrence of flying insects within a few decades: depending on the location, average annual decreases in biomass of 5.2 to 7.5% were recorded. Studies conducted in two nature reserves in the Netherlands showed similar developments in nocturnal insect species. The results are not comparable with those of the Entomologischer Verein Krefeld e.V., as other traps were used (light and ground traps) and nocturnal insects were studied. However, there was also an annual decrease of 9.2% for caddis flies (2009–2017), 3.8% for moths (1997–2017), and 5% for beetles (1997–2017). Overall, declines in the number of individual were observed in almost 40% of the species studied (HALLMANN et al. 2018). The results correspond to the trends that were also determined for individual species.

It should be emphasised that both of the above mentioned studies were conducted in protected areas. SCHUCH et al. (2012) and WENZEL et al. (2006) also report a drastic population reduction of cicadas and a significant decline in butterfly species in protected areas in different regions of Germany. These observations are particularly surprising and worrying, since they concern areas that serve as refuges for wild flora and fauna species and as protection for endangered species. The fact that their conservation goals are not being achieved is demonstrated both by the particularly negative population trends of Red List species (WENZEL et al. 2006) as well as by the serious quantitative decrease in insect biomass (HALLMANN et al. 2017) in protected areas.

14. Apart from studies on butterflies and bees, long-term studies and monitoring data on other insects at a global scale are rare and usually date back only a few decades (IPBES 2016; MIHOUB et al. 2017). They are therefore far from being able to map the entire period of anthropogenic influences. Studies tend to be carried out on a regional level. There are only a few large-scale studies and few that deal with the composition and structures of insect communities. Exceptions to this are the extensive monitoring programmes for the implementation of the Water Framework Directive concerning the macrozoobenthos (paragraph 5). However, the studies carried out to date show a clear trend towards considerable population losses in most of the insect species studied. At this, studies from terrestrial habitats point to a decline, particularly of specialised insect species, whereas generalists are less affected by a decline (HABEL et al. 2016; BIESMEIJER et al. 2006).

15. Since insect species react more quickly to biochemical changes in their environment than more long-lived animal or plant species, population changes can be an early warning signal of environmental changes, for example the water quality of rivers or lakes (SCHOWALTER 2016). Their decline may thus also herald similar developments in other taxa (THOMAS et al. 2004). In addition, it can have a direct effect on insectivorous species due to decreasing food supply. Because of their functional relationships with various areas of the environment (paragraph 16 et seq.), the loss of insects can cause a domino effect which, for example, leads to population changes of other animal species and decreasing biotic pollination of plants, and thus also directly affects humans (BIESMEIJER et al. 2006).

Relevance for the ecosystem and humans

16. Alongside humans, insects have the greatest influence on ecosystems outside the oceans (SCHOWALTER 2016). This is explained on the one hand by the enormous diversity and abundance of this group of animals, and on the other hand by their central role in the functioning of almost all ecosystems. In addition to bacteria, isopods, diplopods and worms, some species of insects (e.g. larvae of many species of dipteran and termites) are also important decomposers that break down dead plant material, fungi and dead animals into their components. Through comminution, digestion and excretion, they break down organic matter, feed it back into the nutrient cycle and thus promote soil fertility. This treatment can also reduce the release of gases harmful to the climate and health (including carbon dioxide (CO2) and methane (CH4)) from decaying plant matter (GRIMALDI and ENGEL 2005). For example, the most common dung beetle species in the leaf horn beetle family have a major impact on the release of climate-relevant gases from cow dung and can reduce greenhouse gas emissions, expressed in CO_2 equivalents, by up to one third (compared to decomposition without beetles). In contrast, the moon horn beetle Copris lunaris decomposes dung quickly and reduces a lot of CO_2, but at the same time contributes to a relative increase in methane emissions. This illustrates how complex the relationships are and how large the influence of species composition is (PICCINI et al. 2017).

17. Insects also pollinate a large number of trees and other flowering plants. In general, the pollination is differentiated between abiotic pollination by wind or water and biotic pollination by animals (90% of pollination). Biotic pollination is predominantly done by insects, although birds and bats also play an important role in the tropics. Insects contribute to the reproduction and formation of fruits, through pollination (MERCKX et al. 2013), with which they also decisively influence the landscape. 85% of the 250,000 flowering plant species worldwide are pollinated by insects, including the majority of wild plants (90%) and many crop plants (GRIMALDI and ENGEL 2005). Throughout the world, three quarters of the world's major plant-based foodstuffs benefit from insect pollination to a varying degree (KLEIN et al. 2007). For higher yields nutritive high quality crops such as pome fruits and many berries, vegetables and spices, are particularly dependent on pollination. An economic analysis conducted by the University of Hohenheim calculated for selected cultivated plants in Germany that a total failure of insect pollination, for example, would lead to a 65% drop in the yield of some tree fruits (apples, sweet cherries, plums, pears and sour cherries), as well as some shrubberies (blueberries, raspberries and blackberries) and cucumbers. For some vegetable crops, such as courgettes and pumpkins, a decline of up to 95% would be possible, while for other vegetables, such as green beans, tomatoes or peppers, it would be much lower at 5% (ORÉ BARRIOS et al. 2017). A few crop plants either require no pollination at all or no insect pollination, but are for example instead wind-pollinated. These are also plants with a high production volume such as wheat, maize, potatoes or sugar cane (WILLIAMS 1994; KLEIN et al. 2007; LEONHARDT et al. 2013). However, the majority of other crops in Europe depend on insect pollination. Although there are regional differences, the production volume of these plants is generally increasing (LEONHARDT et al. 2013). Agricultural production and in particular the food supply thus depend increasingly on pollination by insects (IPBES 2016).

18. The morphology of biotically pollinated plants matches with the morphology of the pollinators they attract. Their diversity is therefore inseparably linked to the diversity of plant species (see paragraph 19). A loss of insects therefore also leads to a loss of plants that depend on insects for their transmission of pollen (DIRZO et al. 2014). In addition to the agricultural plants mentioned above, this also applies to those that determine the species richness of the vegetation of semi-natural habitats and that are important food sources and habitats for animals. The diversity of insects is therefore closely related to the diversity of other animal species.

The diversity of pollinators

19. In the public debate, the honey bee is often associated with the pollination of plants. The population of the honey bee is closely related to its cultivation (beekeeping), which has in Germany increasingly been taken up in recent years, also in cities. After previous heavy losses, the honey bee population in Germany has therefore been following a positive trend over the past years. Unlike other insects, the honey bee is domesticated. From an economic perspective, it is considered the third most important domestic animal after cattle and pigs due to its pollination performance (BLE 2017). However, honey bees are far from being the only pollinators. Out of more than 20,000 bee species worldwide, the western honey bee (*Apis mellifera*) and the eastern honey bee (*Apis cerana*) are best-known. However, the non-domesticated wild bee species (561 established species in Germany, BfN 2011) are also almost all pollinators, as are a large number of other insects. In particular, this applies to the world's more than 120,000 fly species, which are the second most common flower-visiting insects. In addition, butterflies, wasps, beetles, thunder flies, birds, bats and other vertebrates transmit flower pollen (IPBES 2016). For Great Britain, it has been shown that wild bees provide the majority of pollination (BREEZE et al. 2011). Due to differences in both the morphology of plants and in their flowering times, it is essential that pollinator and plant "match". This means that a greater species diversity of pollinators enables more effective pollination of plant species and at the same time a greater variety of flowering plants covers the requirements of a different insect species (BLÜTHGEN and KLEIN 2011; KLEIN et al. 2007). Such coordinated plant-pollinator networks are susceptible to changes as a result of decisive influencing factors such as the flowering times during the year, the presence of different pollinator and plant species, or the pollinator behaviour. A loss of species diversity of pollinators and plants or changes in the onset of flowering and food supply can impair the interplay of pollinators and plants, and thus the pollination performance (BURKLE et al. 2013). The diversity of pollinating insects therefore makes an important contribution to human food security (LEONHARDT et al. 2013).

20. Furthermore, insects are an important part of food webs and thus an important food source for many other animals such as birds, amphibians, reptiles, fish, bats, and mammals such as shrews. In the absence of insects, they are deprived of an important part of their food supply. The number of birds (i.e. abundance) in the agricultural landscape in the EU has decreased by 31.4% between 1990 and 2014 (EEA 2018a). A significant decline particularly in insectivorous bird species has been observed in the recent decades. This is predominantly due to the general intensification of land use, including the use of insecticides and the consequent decline of insects as a food source (HALLMANN et al. 2014). Because of the close connection between sufficient food supply and successful reproduction, the loss of insects is an important factor in the decline of birds (WAHL et al. 2015). 80% of adult individuals of the breeding bird species occurring in Germany feed on animal food, almost half of them on insects and arachnids (ibid.). Over the last 25 years, 30% of the breeding bird species studied have experienced population declines. Over the past 12 years, the decline has accelerated and has affected almost 50% of insectivorous and spider-eating breeding bird species (ibid.).

21. However, insects do not only provide ecosystem services desired by humans, they can also impair the health of humans and animals. So far, this is particularly the case in the tropics, yet due to climate change the risk also increases in more poleward regions. For example, mosquitoes of the genus Anopheles transmit malaria and mosquitoes of the genus *Aedes* transmit yellow fever and Chikungunya fever. Another example is the oak processionary moth, whose caterpillars secrete stinging hairs, which can cause skin irritation, eye irritation, breathing difficulties, and pseudo-allergic reactions on contact (German Bundestag – Scientific Services 2017). Some insect species also cause economic damage in land use. For example, codling moths, potato beetle, phylloxera, cereal aphid or European corn borer feed on crop plants and severe infestations therefore result in high harvest losses. In order to minimise the agricultural damage, pest control measures in land use are taken, especially in agriculture. This, in turn, can have effects on the population of all insects within the range of the application (cf. e.g. Section. 3.2.1). At the same time, the effect of so-called insect pests is often complex. Even the bark beetle, which is dreaded by forest owners due to economic damage (in Germany especially the European spruce bark beetle *Ips typographus* and the six-dentated bark beetle *Pityogenes chalcographos*), fulfils important functions in the forest ecosystem. If it occurs at normal densities, it predominantly infests diseased or dead spruce and contributes to natural forest regeneration through their decomposition (WINTER et al. 2015).

22. In general, the number of insect species that cause crop damage is comparatively low: as predators and parasites or parasitoids insects are involved in elementary ecosystem regulation processes. In many agricultural systems, they prevent mass reproductions of organisms that cause crop damage and thus provide an indispensable ecosystem service (Naturkapital Deutschland – TEEB DE 2016). A greater heterogeneity of the agricultural landscape, e.g. through agrobiodiversity, flower strips, mixed crops, flowering under-seeds or self-planted fallow land increases the occurrence of these antagonists. This has a positive effect on natural pest control and can therefore reduce the need for pesticides (TSCHUMI et al. 2015). TSCHUMI et al. (Ibid.) investigated the effect of natural pest control by simple measures on winter wheat fields in Switzerland. The presence of species-rich flowering strips led to a significantly lower density of the cereal leaf beetle Oulema sp. from the leaf beetle family on the wheat field due to the natural competitors occurring there. Compared to winter wheat fields without flowering strips, the number of larvae of the cereal leaf beetle decreased by 40%, that of adults of the second generation was reduced by 53%, and the damage to plants by 61% (ibid.). The effects of natural pest control can also be seen in the example of the seven-point ladybird. In cage experiments, five to ten ladybirds and their offspring per square metre of wheat field were able to control infestation of cereal aphids (FREIER et al. 2007).

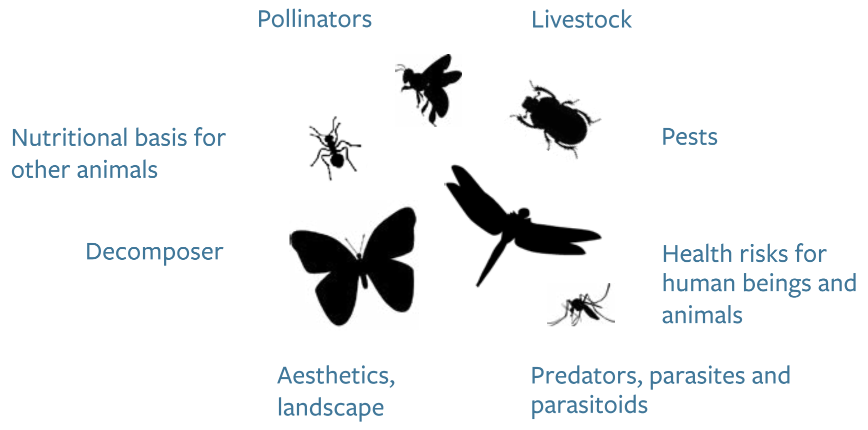
Figure 7 gives an overview of the various functions and meanings of insects in the ecosystem.

Pollinators – Farm animals – Pests – Health hazards for humans and animals – Robbers, parasites and parasitoids – Aesthetics, landscape – decomposers - Food basis for other animal species

23. A high level of biodiversity is important for the adaptability and resilience of ecosystems and thus also for an earth in which humans and other living creatures find beneficial living conditions. Against the backdrop of the functional relationships between insects and ecosystems, the dramatic loss of insects very clearly shows what effects this has on the biosphere as a habitat for humans. GRIMALDI and ENGEL (2005, P. 4 f.) describe this impressively: “Remove all vertebrates from earth […] ecosystems would function flawlessly, particularly if humans were among them. […]. But if ants, bees, and termites alone were removed from the earth, terrestrial life would probably collapse.“ Scientists assume that the global biosphere is already so impaired today that mankind no longer moves in a “safe operating space” (STEFFEN et al. 2015).

Figure 7

Importance of insects in the ecosystem and for humans



SRU 2018

3 Causes of insect decline

24. The basic causes of insect decline are well known (Fig. 8). However, there are knowledge gaps regarding the respective contributions of the individual factors and how they interact with each other. These factors include the loss of habitats, for example through the destruction of hedges, shrubs, wayside margins and small water bodies, as well as the isolation of habitats due to fragmentation (chapter 3.1). The increasing homogenisation of the landscape in recent decades, including the cultivation of very few crops, has also had a negative impact. The quality of the remaining habitats with regard the various demands of insects is decreasing more and more. Substance inputs (pesticides, nitrogen and phosphorus) play an important role as well (chapter. 3.2). There are also other factors such as light pollution (chapter 3.3) and the impacts of climate change (chapter 3.4). While major changes in the landscape structure, such as land consolidation, were carried out several decades ago (SRU 1985) and are being gradually continued, substance inputs have increasingly become significant (SRU 2015; 2016, chapter 6). This statement focuses on the main causes of insect decline described below, which affect large areas, particularly in agricultural and forestry landscapes. So far, little is known about further possible effects of environmental influences from industrial and urban areas such as substance inputs, noise and traffic, as well as about the influence of invasive species on insects. The latter will not be dealt with in greater depth in this statement.

25. The different factors vary in their influence depending on the region and the ecosystem. In addition, they are of varying importance for different insect groups, which have diverse lifestyles and therefore different ecological requirements (paragraph 8 f.). Even within a species, larvae and imagines can have very different lifestyles and sensitivities to environmental changes. In general, many of the stressors act simultaneously on insect populations and reinforce each other. This leads to complex interactions and self-reinforcing processes (BROOK et al. 2008; OLIVER et al. 2016; LIESS et al. 2016; GRUBISIC et al. 2018). These spatial causal relationships are still largely unknown due to their complexity.

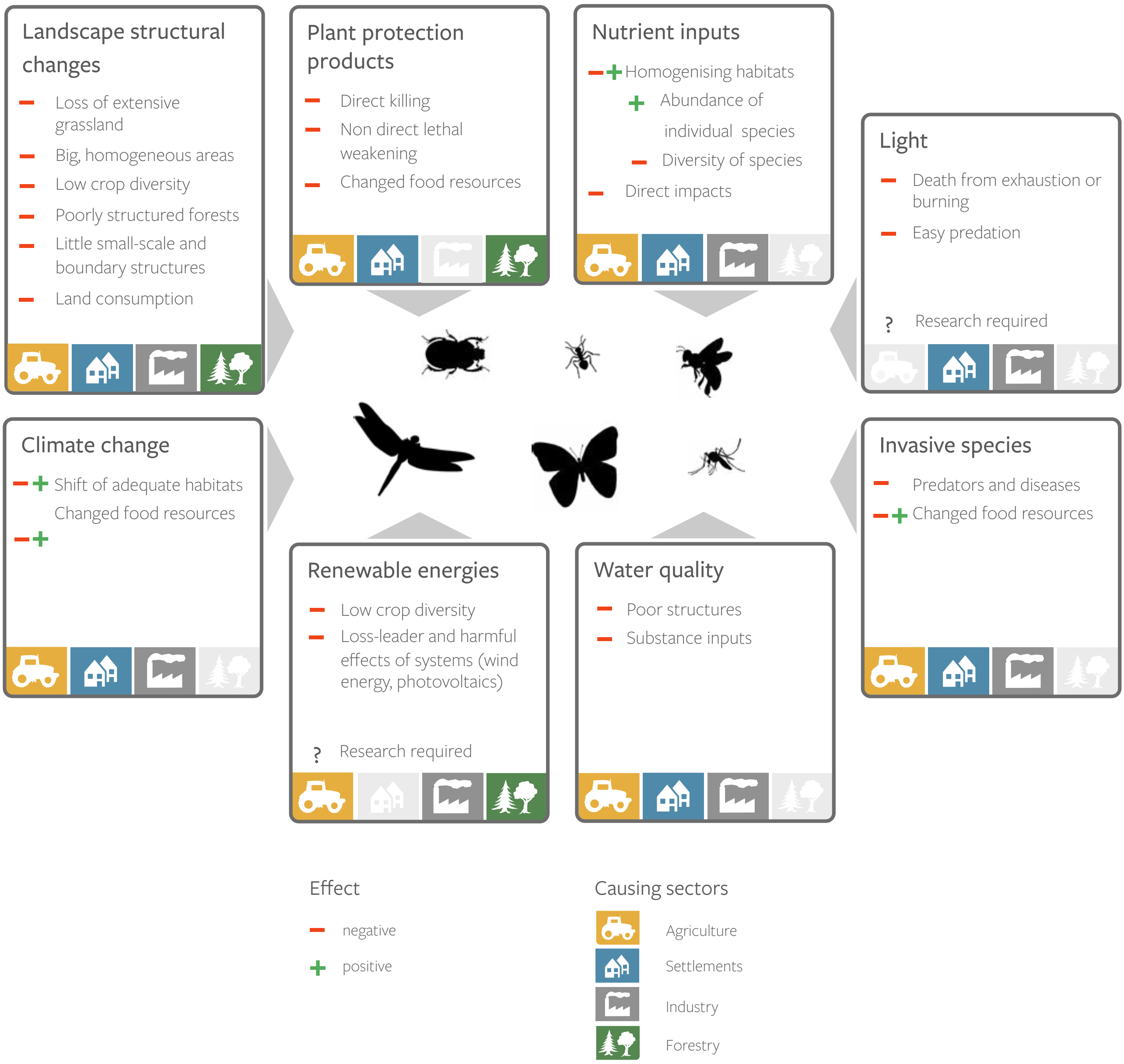
3.1 Structural change of the landscape

26. The loss, degradation and fragmentation of semi-natural habitats are among the major factors for the decline of insects (KENNEDY et al. 2013: THOMAS 2016). They are the result of the constant extension of land used for settlement and transportation as well as changes in agricultural practices. Before synthetically produced fertilisers and pesticides became available, agriculture in Europe had created structurally very diverse cultural landscapes over the past millennia, which offered favourable living conditions for many insect species of the open land. These resembled the park-like landscapes which under natural conditions had been formed by large herbivores (e.g. wild horses, bison). These historical landscapes consisted of many nutrient-poor, open and therefore sunlit areas with a rich diversity of flowering plants, many structural elements with all successional stages of vegetation. Structures such as floodplains, rock piles, deadwood, broken-off edges on hollow paths and shrubs were also common. These landscapes promoted a rich, often thermophilic insect fauna.

27. However, the increasing intensification of land use in recent decades and, in some cases, the abandonment of the use of low-yielding sites nowadays partly reverse this positive effect of agricultural activity. The landscape is being simplified and monotonised. The size of the individual agricultural areas is increasing, the diversity of the cultivated fruit species and varieties, but also that of the accompanying wild herbs, is decreasing. The proportion of fallow land and small structures such as hedges and verges, but also of small and micro water bodies such as puddles or kettle holes is declining (cf. SRU 1985). Over-

Figure 8

Main causes of insect decline



all, the area used for agriculture in Germany has declined compared with the beginning of the 1990s. At this, the surface area of arable land has increased, while the area of grassland has declined (BMEL 2018a, P. 2). Grassland is subject to significant intensification of use, and the decline of ecologically valuable, extensive areas is considerable (Scientific Advisory Council on Biodiversity and Genetic Resources at the BMEL 2015). For example, the share of grassland with high nature value (HNV farmland) of the agriculturally used areas in Germany decreased from 5.6% in 2009 to 5.2% in 2017 (BfN 2017). Of the 75 grassland biotope types on the Red List (biotope types 34 and 35), 83% are classified as endangered (FINCK et al. 2017, P. 63). However, extensive grassland in particular is of considerable relevance for numerous insect species (DI GIULIO et al. 2001; STEFFAN-DEWENTER and TSCHARNTKE 2002). Initial research results indicate that the technology used in mowing also has direct effects on the insect fauna of the grasslands (HUMBERT et al. 2010). However, there is need for further research in this area.

28. The intensification of land use, e.g. through increasing substance inputs (chapter 3.2), increasing mowing frequency and closer crop rotations, reduces the proportion of nesting and feeding habitats for many insect species and retreat areas are lost. The remaining habitats are increasingly isolated and reduced in size, with negative consequences for population development, as well as migration and colonisation movements. Numerous specialised species that have special requirements for their habitat and nutrition are particularly affected. Changes in the structure of the landscape can lead to a general decline in insects as well as a homogenisation of insect populations with a high proportion of generalists (common species) (HABEL et al. 2016). In addition to the intensification of use, in areas with unfavourable agricultural production conditions, abandonment of use also plays a role; against the background of the high demand for land this aspect is probably of less significance. Low-yielding sites are taken out of use, which is accompanied by scrub encroachment (succession) and thus increasing shading and loss of open habitats. Flower-rich plants are displaced and the soil temperature drops, which means that the habitat requirements of many insect species are no longer met. Extensive nutrient-poor and dry grasslands as well as heaths, which are particularly valuable for nature conservation purposes, are affected by this (BfN 2014a).

29. By contrast, small-scale agricultural landscapes with diverse structures, varied crop rotations and a high proportion of extensively farmed grassland with heterogeneous mowing and grazing regimes increase biodiversity and can mitigate or compensate for the effects of intensification at a local level (TSCHARNTKE et al. 2005; KREMEN et al. 2002; JOHST et al. 2015). Structures such as hedges, flowering and edge strips play an extremely important role for insects (HOLLAND and FAHRIG 2000; BROOKS et al. 2012). For example, small arable areas have longer field margins than large ones in proportion to their area and have a greater species' richness of ground beetles (Carabids) (BATÁRY et al. 2017). The loss of edge strips and hedges, for example, has a negative effect on the abundance of moths (FOX 2013). These small structures increase habitat diversity, especially in monotonous landscapes, and thus also the numbers of predatory and parasitic insects, which in turn increases natural pest control (BIANCHI et al. 2006; RUSCH et al. 2016; HAENKE et al. 2009; THIES and TSCHARNTKE 1999; TSCHUMI et al. 2015). The prerequisite for this is that these small biotopes are not exposed to pesticides from neighbouring farms by drift or direct over-spraying, as they can otherwise become deadly traps.

30. In forests, an essential part of the insect species, especially beetles, but also flies and hymenoptera, is bound to the occurrence of old and dead wood (GROVE 2002). They are thus dependent on structures that are common in natural forests but are significantly reduced by forestry use (ibid.). Among the deadwood-dwelling beetles, those which are large, occur in lowlands, and depend on deadwood with a large diameter, deciduous trees, and open spaces are most endangered (SEIBOLD et al. 2015). In the forest too, boundary structures and heterogeneous, small-scale differences in habitat are another important element for insects. The frequency of these varies significantly depending on the forest use, but they tend to be more common in near-natural mixed forests than in forests with few tree species.

31. The often inadequate water quality in hydro-morphological terms (BMUB and UBA 2017) also plays an important role in the decline of many insect species. Many waterbodies are affected by various land and water uses. For example, naturally overgrown riparian strips of water are missing. If there are no typical accompanying woods on the watercourses, their shading function is also lost, causing the water temperature to rise. By river regulation, flow conditions have been standardised. Downstream fish migration has been obstructed by transverse structures. Specific substrate structures have been removed through ground clearance, i.e. sediment removal to ensure, for example, sufficient runoff (LANU SH 1999; Hessian Ministry of the Environment, Climate Protection, Agriculture and Consumer Protection 2016), to name just a few important factors. As a result, suitable habitat structures – especially for more demanding semi-aquatic insect larvae – are often insufficient (BfN 2016).

3.2 Substance inputs

32. In addition to the structural change of the landscape, substance inputs have negative effects on insects. In particular, pesticide and nutrient inputs are relevant causes of hazard. Although nutrient inputs to both terrestrial and aquatic habitats have declined in recent years, they are still significantly higher than ecologically justifiable (for more detail on this SRU 2015). This applies both to the farmland itself as well as other, mostly adjacent, naturally nutrient-poor habitats. Inputs of other substances such as biocides, pharmaceuticals, heavy metals or microplastics are not considered in this statement as it is still difficult to assess their impact on insects.

3.2.1 Plant protection products

33. Plant protection products (or pesticides) are used in agriculture, among others, but also in gardens and parks as well as for maintenance of traffic routes. They are used to regulate or prevent undesirable plant growth, protect seeds and plants from diseases and insect damage, and to protect agricultural products after harvesting. The use of crop protection products such as insecticides, herbicides and fungicides in agriculture is an important cause of the continuing decline in biodiversity (SRU 2016, chapter 6). Insects are particularly affected, both directly and indirectly. The direct damage can occur in many different ways: through the uptake of pollen, nectar, plant material or sap, guttation water or honeydew from treated aphids. Direct contact during application of plant protection products or residues on the plants, in water or in the soil can also have negative effects (IPBES 2016, P. 56). A literature study by BRÜHL et al. (2015, P. 15 ff.) shows that numerous studies have found negative effects of the use of pesticides on biodiversity and abundance of insects. Insecticides thus also have an effect on the food chain and the quality of agricultural habitats, for example for breeding birds in agricultural landscapes (JAHN et al. 2014; HALLMANN et al. 2014).

34. Despite considerable progress in recent decades to develop and apply pesticide active substances more precisely and to reduce the undesirable side effects on humans and the environment, neither the overall application quantities have decreased nor have the negative effects on ecosystems been reduced (SRU 2016, chapter 6). Domestic sales of plant protection active substances in Germany remain at a high level (BVL 2017).

35. Special political and social attention has been paid to the group of active substances known as neonicotinoids, which act systemically and, as nerve toxins, can influence the behaviour of insects, for example pollinators such as honey bees (see SRU 2016). They can have lethal or sublethal effects and affect locomotor activity, memory, learning, foraging and reproduction (FELTHAM et al. 2014; STANLEY et al. 2015; EL HASSANI et al. 2008; DECOURTYE and DEVILLERS 2010; WHITEHORN et al. 2012; RUNDLÖF et al. 2015; DESNEUX et al. 2007). Exposure to several active substances may result in combination effects. These are hardly known due to the large number of active substances used and their possible interactions (GILL et al. 2012). In spring 2018, the European Commission banned the use of the three active ingredients clothianidin, imidacloprid and thiamethoxam in the field (European Commission 2018a). However, other neonicotinoids and other active substances with similar modes of action will continue to be used. There are also clear indications that small water bodies in the agricultural landscape are negatively affected by the use of pesticides. Study results indicate, for example, impairments of sensitive invertebrate species in Germany (MÜNZE et al. 2015). As was expected, the risk of damaging aquatic invertebrates or insects through the use of insecticides is particularly high (SCHÄFER et al. 2017; SZÖCS et al. 2017; BERGHAHN et al. 2012).

36. Herbicides have mainly indirect effects on insects by reducing of the arable flora and undesirable flowering plants in the garden (BOHAN et al. 2005; PLEASANTS and OBERHAUSER 2013). Although the herbicide glyphosate, the most frequently used pesticide in Germany in terms of quantity (UBA 2014; SRU 2016, paragraph 399) exhibits very low ecotoxicity in standard tests (EFSA 2015), it reduces the food supply and habitats for insects. This in turn can have indirect effects on competition, predation and parasitism through trophic relationships. In addition, BALBUENA et al. (2015) found evidence on the influence of glyphosate on the flight and orientation abilities of honey bees. Critical in this context, apart from the large-scale use, is the “thoroughness” with which the plants are eliminated by the broad-spectrum effect of most herbicides. However, it does not ultimately matter to the insects whether the food supply and habitats are reduced chemically or mechanically. An influence of herbicides on the natural vegetation outside cultivated areas, for example due to drift, is to be expected, but has not been investigated in detail.

3.2.2 Nitrogen and phosphorus

37. The input of reactive nitrogen compounds from agricultural and combustion processes in transport and industry is another important cause of biodiversity loss, both in terrestrial (McCLEAN et al. 2011; SALA et al. 2000; SUTTON et al. 2011) and in aquatic ecosystems (HELCOM 2010; OSPAR COMMISSION 2010; BMUB and UBA 2016). Key mechanisms are eutrophication and acidification, which change the species composition, reduce the number of species and weaken the resistance of ecosystems to disturbances. This leads to irreversible and hardly foreseeable consequences in the entire food web.

38. Ammonia emissions in the air are particularly relevant for terrestrial habitats. They make up almost two thirds of nitrogen emissions in the air and almost half of the total annual nitrogen emissions in Germany. They originate almost exclusively from agriculture (UBA 2017). The amended NEC Directive EU/2016/2284 obliges Germany to reduce its ammonia emissions by 29% between 2005 and 2030. The Directive stipulates that the Member States must draw up a national clean air programme by the end of March 2019 setting out the measures to be taken to achieve the reduction obligations. This will be particularly difficult with regard to reducing ammonia emissions from agriculture, which have not fallen in the last twenty years. There is great potential for reducing emissions, but this potential has by no means been exploited by the measures adopted to date (SRU 2015, Paragraph 336). Since agriculture is the largest emitter of nitrogen compounds, it is the focus of consideration here. With regard to nitrogen emissions from combustion processes in industry and transport and recommendations for their necessary reductions, reference is made to the special report of the German Advisory Council on the Environment (SRU) “Stickstoff: Lösungsstrategien für ein drängendes Umweltproblem“ (SRU 2015).

39. In terrestrial systems, the consequences of nitrogen deposition have an indirect effect on insects, for example through the loss of food plants and associated habitat structures and the resulting monotonisation of habitats. Resulting from increased nitrogen inputs, plant growth increases, shading increases and soil temperature decreases. The soil-based processes in the life cycle are therefore slower. However, many insect species require sunny areas on the ground for nesting. In addition, the material composition of the food plants changes and thus impairs the nutrient supply of the larvae (FEEST et al. 2009). Nitrophobic food plants disappear as a result of nitrogen inputs (ibid.). These nitrogen inputs have a negative effect on plant species diversity and flowering density, which in turn can have negative effects on the number of species and frequency of pollinators as well as the frequency of flower visits (EBELING et al. 2008). ÖCKINGER et al. (2006) found, for example, a decrease in butterfly species whose host plants require nutrient-poor conditions. The decline in the number of species and the abundance of cicadas on dry grasslands in eastern Germany over a period of forty years (periods covered by the study: 1964 – 1966 and 2008 – 2010) is also primarily attributed to nitrogen deposition, the intensification of agriculture and the associated changes in vegetation composition (SCHUCH et al. 2012). Long-term nitrogen inputs lead to impoverishment of both plant and insect communities in grassland. Analogous to plants, whose species richness decreases and whose biomass increases as a result of nitrogen inputs, the species richness of insects may also decrease, while their biomass, especially that of herbivores and stock waste decomposers, may increase (HADDAD et al. 2000).

40. Nutrient inputs into surface waters can lead to eutrophication. In inland waters, phosphorus is often the determining nutrient. Despite sometimes significant reductions in phosphorus inputs, this continues to be a challenge for water protection (BMUB and UBA 2017). Eutrophication is particularly noticeable due to algal blooms, increased water turbidity and oxygen depletion in deep water layers due to the increased decomposition of biomass. These effects are particularly serious when nutrient-poor (oligotrophic) water systems are put into a nutrient-rich (eutrophic or hypertrophic) state. This has serious consequences for aquatic biodiversity and also affects insects. Oligotrophic waters are particularly susceptible to substance inputs and are often home to specially adapted and rare species (ETC Water 2010). In addition, nutrient inputs combined with elevated temperatures promote the growth of blue algae (cyanobacteria) in waters that alter the species composition of invertebrate organisms (including insects) (CHAURASIA 2015).

3.3 Light pollution, climate change and renewable energies

Light pollution

41. Increasing light pollution has a significant impact on the environment, human health and energy efficiency (HELD et al. 2013). Light has an attracting effect on numerous insect species. Two thirds of invertebrate species are nocturnal (HÖLKER et al. 2010). With the increase in populated areas, the number of artificial light sources also increases, a process often described by the term “light pollution”. It is only in recent decades that the subject has gained significant scientific attention, and many relationships and effects, particularly at the ecosystem level, are not yet sufficiently understood. However, previous research has shown that artificial light sources influence behaviour such as foraging, mating and migratory behaviour, reproductive success and survival of nocturnal insects. This can change the occurrence and composition of insect communities (GRUBISIC et al. 2018; NAVARA and NELSON 2007; HÖLKER et al. 2010; BRUCE-WHITE and SHARDLOW 2011). This applies not only to flying species, but also for ground-living species (DAVIES et al. 2012). Many insects are attracted to light sources and fly around them, sometimes until they die of exhaustion or become easy prey for predatory animals. Artificial night lighting can thus influence food chains and ecosystems (HÖLKER 2013, P. 75), which in turn affects their functions (HÖLKER et al. 2010). The irritation, attraction and collision effects depend on the spectrum of the light, the illuminance and the case construction as well as the respective insect order (EISENBEIS 2011; BRUCE-WHITE and SHARDLOW 2011; LONGCORE and RICH 2004). The changes also have indirect effects on day-active animals and the entire ecosystem, for example through changes in the food supply. The extent to which light pollution contributes to the threat of individual insect species or to a significant decline in insect populations has not yet been sufficiently investigated, but significant effects are to be expected (EISENBEIS 2013; HÖLKER 2013; WILSON et al. 2018). First results indicate a high relevance of light increase for the decline in moth populations in Great Britain and Ireland (WILSON et al. 2018).

Climate change

42. The effects of climate change are manifold and can result in changes to insect populations (IPBES 2016). Abundance and community structure, phenology, physiology, behaviour, and reproduction can be influenced (MUSOLIN 2007; RADENKOVIĆ et al. 2017). For example, pollinators show changes in distribution, abundance and seasonal activity patterns (life cycles and interaction between species) (IPBES 2016). Thus, the originally evolutionary coordinated times of plant flowering and the activity of corresponding pollinators may no longer match due to climate change (plant pollinator networks, see paragraph 19; BURKLE et al. 2013). Depending on ecological demands, the local effects can be positive or negative for individual species. Cold-loving species that are already at the upper extreme end of their temperature tolerance range may be lost (locally), while thermophilic species may spread further towards the pole (FOX et al. 2014). Changes due to climate change also require insects to adapt to other living conditions. The ability of insects to spread is central to this, but is not precisely known for many species. All this can lead to a reduction in the range of species, with insects being at greater risk than other animal groups (WARREN et al. 2018).

It can take several decades before the effects of climate change on insects and their functions become fully visible as ecological systems often react with a time delay. Despite all the methodological difficulties and inaccuracies associated with modelling, models indicate that by the end of the 21st century a significant proportion of pollinators in Europe could be endangered or extinct as a result of climate change, depending on the climate scenario and the dispersal capacity of individual species (SETTELE et al. 2008; RASMONT et al. 2015; WARREN et al. 2018).

Renewable energies

43. The use of renewable energies has direct and indirect effects on insects in various ways. This applies to the cultivation of biomass as well as to photovoltaic and wind energy plants. The cultivation of bioenergy crops can have different effects on insect populations, depending on the type of plant cultivated, the surrounding landscape and the group of insects considered (DAUBER and BOLTE 2014). Thus crops such as oilseed rape, which have a large number of flowers at the same time, can increase the species richness of bees and wasps by providing food resources in the short term. However, as soon as they are harvested, a so-called *Trachtluecke* arises, in which pollinators suddenly find no more food. At landscape level, therefore, more long-term, near-natural elements are needed to maintain viable populations of flower-visiting insects (see Paragraph 29; DIEKÖTTER et al. 2014).

The effects of photovoltaic and wind energy plants on insects are still little known. Wind turbines can attract flying insects, as they visit the turbines to search for food, or as a place for resting or reproduction and get trapped there (CORTEN and VELDKAMP 2001). A study by LONG et al. (2011) which examined the effects of different turbine colours found out that white and light grey turbines attract most insects. The thermal properties of the turbines may also have an attracting effect. The insects themselves may attract predatory animals such as birds and bats in turn, thereby increasing their risk of collision with wind turbines (VALDEZ and CRYAN 2013). Photovoltaic systems are sources of polarised light and can therefore attract insects (HORVÁTH et al. 2010; HERDEN et al. 2009, P. 81 et seq.). This is expected to affect in particular aquatic and semi-aquatic insects that confuse the installations with water surfaces. The design of the solar modules and their positioning in relation to water bodies may have a significant influence on the attracting effect (HERDEN et al. 2009). Since the lure and trap effects of photovoltaic and wind energy plants and their influence on the populations of certain insect species have not yet been sufficiently investigated, there is a need for more research in this field.

4 Recommendations for action for an efficient and area-effective insect protection

44. The following recommendations for action are in line with the basic idea of risk research as expressed in the "je-desto" formula: "The greater the importance of the endangered good and/or the greater the damage to be feared, the lower the requirements for the probability of occurrence which should be set" in order to be able to assess the risk "as no longer acceptable (in the sense of unacceptable)" (KLOEPFER 1993, P. 65; WBBGR 2018). In the case of insects, the available data indicate a dramatic decline in the population of many species (see Paragraph 10 et seq.). Due to the complex, diverse causes, the Federal Government and the federal states must immediately take various complementary measures to slow down this decline in the short-term and stop it in the medium-term. If the identified trends in decline continue, this will lead to permanent loss of a number of species in the near future. This affects key components of our ecosystem with far-reaching, downstream effects, including for humans. This is particularly threatening against the background that it cannot be foreseen to what extent climate change will additionally endanger insect species in the long term. Scientific findings therefore even now require rapid and effective action. In the following, various recommendations for action are made to the federal and state governments. These are, of course, not exhaustive and comprehensive. In this context, accelerating climate change is also of crucial importance and requires immediate action, on which the SRU has already commented elsewhere (SRU 2017a; 2017b; 2011). Little is yet known about the influence of invasive species and their possible contribution to insect decline.

45. In order to stop the decline of insect populations and their ecological and economic impact, selective or short-term measures are not sufficient. Based on the key issues paper already adopted, the Federal Government's planned Action Programme for Insect Protection must therefore focus on large-scale, long-term effectiveness and ensure immediate and concerted action by the relevant decision-makers. At this, agriculture plays a key role – for example through the EU's Common Agricultural Policy (CAP) – not least because of its relevance to area. The Federal Government's planned arable farming strategy and the announced, yet still pending cultivated grassland strategy announced by the Federal Ministry of Food and Agriculture (BMEL) must also become effective for insect protection.

The relevant departments of the Federal Government (the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the BMEL, and in case of monitoring and research, the Federal Ministry of Education and Research (BMBF)) should jointly initiate the Action Programme for Insect Protection. For an effective action programme, measurable objectives must be defined and backed up with concrete measure and responsible actors. The objectives should be integrated into a system of indicators and the impact of the measures should be analysed through statistically and biologically meaningful monitoring of insect diversity (not only for individual groups such as butterflies or grasshoppers). The programme should be developed and implemented in close cooperation with the Federal States. At the national level there are already some relevant objectives in the national biodiversity strategy and the German sustainability strategy (e.g. nitrogen surplus, land usage, organic farming). However, their indicators are far from the target value or are even moving away from it. In some cases, the objectives have not been achieved in the past and yet were been ambitiously developed further, but continued almost unchanged..

46. Due to the urgent problem situation, the following recommendations for action should be initiated and implemented immediately (Fig. 9). The SRU and the Scientific Advisory Board for Biodiversity and Genetic Resources (WBBGR) see priority measures in making land use more insect-friendly, not only selectively, but on a large scale. Monitoring should also be substantially developed further. These measures are regarded as priorities (priority measures) and should be specifically supported by further measures, also related to substances and area (complementary measures). These should be accompanied by measures for communication, knowledge generation and education.

Overall, insect protection has many synergies with other biodiversity and environmental objectives of the Federal Government, for example on land use, organic farming,

Figure 9

Overview of the recommendations for action

Priority actions	Supplementary actions	Flanking actions
Making land use more insect-friendly	Making land use more insect-friendly	Improve communication, sensitize the public
• Use CAP reform • Develop contractual nature conservation and make it financially attractive • Extend organic farming • Maintain and create heterogeneous landscapes • Empower green infrastructure: fully establish the biotope network • Designate and protect riparian strips and refuges • Significant reduction of total usage and environmental impacts of pesticides • Implement integrated pest management techniques • Strict implementation of amended fertilizer legislation	• Increase the effectiveness of intervention regulation • remedy deficits in authorisation procedures for plant protection products with regard to risk assessment • Determine ambitious programmes with actions to decrease nitrogen inputs	• Create more spaces to experience nature • Enhance environmental education in the field of insects • Sensitize the wider public in their consumer habits • Promote voluntary engagement and Citizen Science
	Reduce land use for settlements and traffic	Closing the knowledge gap
	Lower negative effects of lighting	Increase training and development
Substantial development of insect and biodiversity monitoring	Strengthen existing protected areas	

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nitrogen surplus and biodiversity in the German Sustainability Strategy, numerous objectives of the national biodiversity strategy, but also the objectives of the Water Framework Directive and the National Action Plan for the Sustainable Use of Plant Protection Products (NAP) (including the promotion of beneficial insects through the creation of retreat areas, among others).

4.1 Making land use more insect-friendly

4.1.1 Aligning agricultural subsidies with ecological concerns

Using the CAP reform

47. The currently dominant forms of agricultural management are a central driver of insect loss. The future design of the CAP is therefore of crucial importance for insect protection. While the "greening" of the area-related direct payments ("first pillar" of the CAP) has done very little to protect biodiversity in general and insects in particular, the agri-environment-climate measures within the framework of the integrated rural development policy ("second pillar" of the CAP) are currently the decisive instrument for financing biodiversity objectives in the Member States (SRU and WBW 2017; WBBGR 2018). Therefore, this is an essential lever for effective insect protection. Previous efforts to take greater account of environmental and nature conservation concerns in agricultural policy (greening) have been insufficient to trigger the necessary ecological changes and are therefore economically inefficient (PE'ER et al. 2017). The European Court of Auditors (2017) also comes to the conclusion that it is unlikely that greening will "[...] provide significant benefits for the environment and climate" (ibid., p. 47) and that "[...] greening, as currently implemented, is unlikely to significantly enhance the CAP's environmental and climate performance" (ibid., p. 46).

The SRU and the WBBGR have repeatedly drawn attention to the fact that public funds should only be used for the provision of public goods (WBBGR 2018; FEINDT et al. 2018a). These include nature conservation and environmental protection as well as the conservation and maintenance of a biodiverse, ecologically valuable cultural landscape (SRU 2009; 2013). Within the framework of the ongoing negotiations on the CAP reform, the German Government should make a clear commitment to a reorientation after 2020 that consistently contributes to biodiversity protection (WBBGR 2018).

48. The worrying situation and negative trends in biodiversity in agricultural landscapes, and in particular the situation of insects, require greater efforts of agriculture to protect biodiversity and other environmental goods at the European level. The Federal Government should work to ensure that ambitious uniform environmental standards are already established at EU level. In its proposal for the post-2020 CAP published on 1 June 2018, the European Commission envisages, among other things, merging the existing cross-compliance regulations with the current greening components (European Commission 2018b). However, the proposal stipulates that the design of essential elements should be left to the Member States. This entails the risk that individual Member States will lower environmental standards in order to save costs of their producers. Increasing national leeway in the next funding period, which is currently becoming apparent, should instead be used to strengthen environmental and nature conservation concerns at national level. A differentiation of the area-related direct payments according to the characteristics of the respective agricultural areas that influence biological diversity should be sought (FEINDT et al. 2018b; WBBGR 2018).

At national level, the legal obligations defined in good professional practice should also be clarified in order to better implement, review, and enforce them (SRU 2015, paragraph 409 f.)

Expand contractual nature conservation and reward it more attractively

49. In order to stop the progressive loss of insects and biodiversity as a whole, effective nature conservation measures are necessary for which sufficient financial resources must be available in the long-term (SRU and WBW 2017). Strengthening the use of public funds for the common good also opens up opportunities for land users. Greater remuneration for the good of "nature conservation" can offer economic alternatives, especially in agriculturally disadvantaged regions, which are often characterised by particularly high biodiversity (ibid., paragraph 34). Existing support programmes for agri-environment-climate measures should also be better funded than before in order to encourage more farmers to participate in contractual nature conservation (SRU 2016, paragraph 474). This applies in particular to effective programmes to promote species-rich grassland, which is of great importance for insect diversity (WBBGR 2015; 2016; 2018). Above all, the implementation of so-called "dark green measures", i.e. measures with high ecological effectiveness, should be intensified. Against this background, it is urgently necessary to increase funding under the second pillar of the CAP in order to implement targeted insect protection measures in the agricultural landscape. The Commission's current proposals for the coming funding period, which provide for a disproportionate reduction in the second pillar, must therefore be viewed with great concern.

Further expanding organic farming

50. Also because it does not use synthetic fertilisers and pesticides, organic farming has numerous positive effects on insects. Studies have shown that the biodiversity and abundance of insects in organic farming are often higher than in conventional farming, especially in intensively farmed landscapes (INCLÁN et al. 2015; POWER et al. 2016; BENGTSSON et al. 2005). The German Sustainability Strategy includes the goal of increasing the share of organically farmed land in the total agricultural area from 7.5% in 2016 to 20% in the future (Federal Government 2017; BMEL not dated). It is gratifying to see that the Federal Government has now agreed in its coalition agreement to achieve this goal by the year 2030 (SRU 2016, paragraph 475). The recent increase in subsidies in numerous Federal States has contributed to an expansion of ecological production. This is a positive step and the Federal Government should continue the process begun with the "Organic Farming – Looking Forwards" strategy (BMEL 2017) in a targeted and rapid manner. The promotion of organic farming by the Federal States should be further expanded.

4.1.2 Promoting diverse landscape structures

Conservation and creation of heterogeneous landscapes

51. Diverse habitats on different spatial scales can contribute decisively to more biodiversity in agricultural landscapes (BENTON et al. 2003). In future, agricultural subsidies should therefore support heterogeneous landscape structures much more effectively than before, for example through targeted premiums for landscape diversity (FEINDT et al. 2018b). More structural elements such as flower strips, field margins and hedges can counteract the loss of insects, especially in landscapes that have become structurally poor due to the current form of land use.

In order to protect or restore biodiversity in agricultural landscapes, a share of 10 to 20% near-natural areas is often considered necessary in the literature (HOLZSCHUH et al. 2011; HOFFMANN et al. 2012; HOTES and EBERMANN 2010; UBA 2010; SRU 1985). On these areas, no fertilisers or pesticides may be used. To this end, farmers should be able to obtain advice on the design of the structural elements. Also, some specifications must be made for the use of these areas. Soil regeneration periods and regular maintenance are important prerequisites for high habitat quality for insect diversity and the biodiversity of the agricultural landscape as a whole. The use of the plant cover, for example the mown vegetation, as animal feed or in energy production, does not necessarily conflict with the desired ecological performance of the areas (WBBGR 2012). This must also be adequately taken into account when designing the ecological priority areas within the framework of the new conditionality of the direct payments, i.e. the environmental and climate protection requirements.

Landscapes should also show extensively used grasslands with many different mowing and grazing regimes (WÄTZOLD et al. 2016). Thus, on the one hand extensive scrub encroachment can be counteracted, on the other hand, the spread of flowering plants can be promoted and a nutrient-poor level maintained through adapted mowing times. Diverse crop rotations on farmland can also have a positive effect, as long as they do not contribute to an overall more intensive use. Fallow land, riparian strips and field margins as well as buffer zones around intensively farmed areas are important nesting and feeding habitats for insects and should be maintained or newly created (TSCHUMI et al. 2015). When pesticides are used, a sufficient distance from these landscape elements must be maintained in order to protect them from negative impacts.

The cultivation of biomass for energetic or material use should also be designed to be as insect-friendly as possible. Ecologically grown, flower-rich bioenergy crops, for example in mixed crops or as flower strips, can promote landscape heterogeneity and contribute to insect protection. On the other hand, bioenergy crops should be viewed critically in large-scale monocultures (SRU 2007a; 2011).

52. In aquatic areas, the restoration of near-natural habitats through structure-enhancing, hydromorphological measures is decisive for good ecological status (BMUB and UBA 2016), and thus also for the conservation and restoration of insect diversity. This includes, for example renaturation of watercourses, including the dismantling of barrier constructions and creation or restoration of alluvial zones and corresponding overgrown water margins (see also BMUB and BfN 2015). A large number of measures are already being taken to implement the Water Framework Directive (BMUB and UBA 2016). Nevertheless, only about 8% of surface waters currently achieve good status (BMUB and UBA 2017). For this reason, too, the activities for the implementation of the Water Framework Directive must be given appropriate importance.

53. Of the many insects occurring in the forests, those that are dependent on old and dead wood as well as on structures along forests' edges are primarily at risk (paragraph 30). Non-managed forests or parts of forests, but also deadwood islands, can therefore be important refuges for these species and their share should be further increased, as for instance stipulated in the national strategy for biological diversity (5% forests with natural development, 2% wilderness) (SRU 2016, chapter 5; 2012, chapter 6). In addition, the protection of old, original forests and near-natural management with long rotation periods, which increases the structural diversity of forests, can have a positive effect on beetle communities, for example (LANGE et al. 2014). Many forest-living insect species also require adjacent open-land habitats in certain life phases. Insects should therefore be systematically promoted in sustainably managed forests by applying as many different silvicultural rejuvenation methods as possible as well as by the consistent creation of insect-friendly internal forest structures and transitional areas to the open landscape. In any case, the control of mass reproduction of insects harmful to forests should correspond to good professional practice in the implementation of integrated plant protection in forests and should, as far as possible, include only selective measures.

Strengthening Green Infrastructure: establishing a comprehensive biotope network

54. There are EU-wide efforts to establish a Green Infrastructure to protect biodiversity and the services it provides. Green Infrastructure is defined by the European Commission as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" (European Commission 2013). It covers both rural and urban areas.

At national level, the biotope network makes an important contribution to the implementation of this concept. The Federal Nature Conservation Act stipulates that an inter-state biotope network covering at least 10% of the area of each federal state is to be created. With its core areas, connecting areas and connecting elements, the biotope network makes an important contribution to connect isolated habitats and insect populations, as many insects have only a limited ability to spread. Therefore, the often isolated remains of natural or semi-natural habitats must be protected or restored and reconnected. The responsibility for implementation lies primarily with the federal states. As there is no time limit, implementation has so far been too slow and has been hampered among other things by a lack of financial resources and the general shortage of land (JEDICKE 2015; FRITZ 2013; RECK 2013). Full and rapid implementation is urgently needed and should be completed within ten years at the latest. To this end, the Federal Government should enshrine 2028 as the binding target year for the complete establishment of the biotope network in the Federal Nature Conservation Act. However, this objective must be underpinned by quality criteria that define the necessary prerequisites for areas of the biotope network. The demands of different insect groups on their habitats alone are extremely diverse and can contradict each other. The biotope network should therefore cover as broad a spectrum of different habitats as possible. Agri-environmental measures in the framework of the CAP could provide targeted support for the biotope network. In order to successfully integrate insect protection into this concept, it should be taken into account in local and regional landscape planning.

In the aquatic sector, the Federal Government launched the “Blue Belt Germany” federal programme in February 2017 (BMVI and BMUB 2017). It is intended to contribute to the renaturation of watercourses and floodplains (ibid.) and thus also supports the protection of (semi-) aquatic insects by creating new habitats or improving the quality of existing ones. The Federal Government is now called upon to implement this programme in an ambitious manner.

Making the intervention regulation effective

55. The Federal Nature Conservation Act regulates the compensation of interventions in nature and landscape in Sec. 13 et seq. This refers to changes in the shape or use of base areas or changes in the groundwater level associated with the living soil layer which can significantly impair the performance and functionality of the natural balance or the landscape. Such considerable impairments should be avoided as far as possible. Unavoidable interventions must be compensated for by the polluter, where possible through compensatory or replacement measures and, where this is not possible, through financial compensation. As part of the ecosystem, insects must be taken into account appropriately in the impact prognosis. Corresponding compensation measures should be placed in an ecosystem context and landscape aspects should be taken into account. The various concepts for re-connecting habitats should be included.

With regard to the intervention regulation, however, a considerable lack of enforcement has been noted. In practice, both the implementation rate and the quality of the compensatory and replacement measures are often low. There is no nationwide recording and evaluation of these measures, and findings are often based on samples, random findings and experience. Nevertheless, studies in various federal states have shown that often only roughly half of the defined measures are implemented at all and in only about a quarter of the cases, the implementation was good or very good (ECKER and PRÖBST-HAIDER 2016; Landtag of Lower Saxony 2018). Long-term care measures are also often not carried out to the extent required. A major reason of these deficits in enforcement and follow-up control is the lack of qualified personnel in the responsible nature conservation authorities. In many federal states, nature conservation administrations have been confronted with job cuts for years, while the variety and complexity of tasks is increasing (SRU 2007b; EBINGER 2011; BOGUMIL et al. 2017; 2016; KOTTWITZ 2015; BÖCHER 2016; VOLKERY 2008). Adequately equipped and qualified nature conservation management at regional level is essential for the appropriate implementation of intervention regulation. In addition, publicly available data could strengthen public control. Violations must be sanctioned more severely.

Identify and secure riparian strips and refuges

56. Riparian strips are an important structural element in the agricultural landscape. Appropriate vegetation on these areas additionally increases their function for biodiversity. They are also of great importance in reducing nutrient inputs into watercourses through drainage and runoff. In a similar way, they can also buffer pesticide inputs and veterinary active substances (SRU 2016, paragraph 469). In the past, the SRU had already recommended that riparian strips along natural water bodies should be 10 m wide (SRU 2015; 2016, chapter 6). In addition, the use of fertilisers and pesticides in these strips should generally be prohibited.

Refuges are sections of water bodies which are kept as free as possible from anthropogenic interference and from which polluted sections can be repopulated. For example, they enable symbiotic communities to recover more quickly after the introduction of pesticides (ORLINSKIY et al. 2015). Examples of such refuges are forested areas upstream in watercourses. The provision of refuges is not easy. Yet they could be provided, for example when implementing measures to improve water morphology in the course of the Water Framework Directive, for flood protection or nature conservation. In addition, it should be examined whether the creation of riparian strips and compensation areas in the agricultural landscape is also possible under the conditions for use which are specified in the authorisation of pesticides (see paragraph 62; SRU 2016, paragraph 473; HÖTKER et al. 2018). A major obstacle to achieving good ecological status of water bodies under the Water Framework Directive is the lack of near-natural shore zones or vegetation areas near the shore of water bodies, especially in urban or agricultural areas. An increase in the proportion of small structures near water bodies would serve both, integrated plant protection as well as the objectives of the Water Framework Directive. At the same time, these small structures can prevent chemical inputs into water bodies and in turn represent terrestrial habitats for semi-aquatic insects.

4.1.3 Reducing and focusing the use of pesticides

Significantly reduce the overall use and environmental impact of pesticides

57. The approval of glyphosate was renewed by five years by the European Commission only at the end of last year, following a decision by the Member States (European Commission 2017). Nevertheless, in the coalition agreement the governing coalition has advocated a fundamental end to the use of glyphosate, which is generally to be welcomed (CDU, CSU and SPD 2018, P. 140). However, it should be noted that when phasing out Glyphosate, also the total use and the general environmental impacts of other pesticides, in particular insecticides, as well as herbicides must be taken into account. It is by no means enough to end the use of a single active substance, especially if it is replaced by other active substances which may have similar or even more harmful effects on the environment. In particular, the widespread and purely prophylactic use of total and broad-spectrum pesticides should be discontinued.

For this reason, and also in view of the fact that the application of pesticides entails the risk that they may drift to neighbouring areas, the use of non-chemical methods such as those in integrated plant protection (paragraph 61) should be strengthened. The total amount of pesticides used and their environmental impact must be significantly reduced. In addition to integrated crop protection, other concepts such as environmentally friendly precision farming, i.e. cultivation as targeted and precise as possible, as well as by agro-ecological cultivation concepts contain potential for an environmentally sound approach. Robust varieties and biological pest control offer significant potential against pests and diseases.

With the National Action Plan for the Sustainable Use of Plant Protection Products (NAP), adopted in 2013, the Federal Government has set itself the goal of reducing the risks of plant protection products for humans and the environment (BMEL 2013). The NAP is currently being further developed with regard to the objectives, indicators and planned activities for the protection of biodiversity. So far, the main problem has been that no institution is obliged to ensure compliance with the above objectives and, in case they are not achieved, to initiate countermeasures.

58. The use of chemical pesticides in domestic and allotment gardens and by non-professional users such as hobby gardeners should be stopped immediately. Public areas, such as communal areas, should also be managed without pesticides. In this regard, France could serve as a model, where pesticides outside agricultural areas will be banned completely from 2019 (EurActiv 30/03/2017). In Germany, 240 towns and municipalities have so far spoken out in favour of completely or largely dispensing with pesticides on their communal green spaces as part of the BUND (Bund für Umwelt und Naturschutz Deutschland e.V.) “Pesticide-free municipality” project (BUND 2016). More public and private green spaces in the city should be designed as close to nature as possible, and while selecting the plants special attention should be paid to native and insect-promoting species (SRU 2018). Depending on the design, more extensive management practices may also save on maintenance costs.

Overall, advice on the use of pesticides should be expanded in both the municipal and private sectors. General, large-scale application of insecticides to combat mosquitoes, for example as is done along the Rhine, with unknown effects on the affected ecosystems, should be replaced by targeted and controlled measures that exclude protected areas.

59. To reduce the use of pesticides in Germany, the SRU recommended a levy on pesticides in its Environmental Report 2016 (SRU 2016, paragraph 477 et seq.; see also MÖCKEL et al. 2015). This serves to give farmers an additional incentive to use a fewer pesticides more effectively and price negative environmental effects more strongly. Especially against the background of difficult and costly controls, it could serve as an incentives instrument to supplement regulatory requirements in a meaningful way (SCHÄFFER et al. 2018, P 38). The positive environmental impact of the levy can be increased by a risk-based design (Ministry of Environment and Food of Denmark 2017). Rising prices for pesticide due to the introduction of a levy also mean that integrated pest management measures (paragraph 61) become more attractive for farmers. For a corresponding incentive effect, the levy would have to be set at a sufficiently high level (SRU 2016, paragraph 477 et seq.; MÖCKEL et al. 2015; SALOMON et al. 2017). The revenues from the levy should be used for monitoring, consulting services and protective measures as well as for compensation measures.

60. Users of plant protection products should be better trained as to what possibilities they have to dispense with the products or to use them in a targeted and as environmentally friendly manner as possible. Training of farmers as well as pest controllers should be complemented by environmental impacts, environmentally sound practices, non-chemical alternative methods, integrated control measures and appropriate good professional practices.

Systematic implementation of integrated plant protection

61. The German Plant Protection Act (PflSchG) stipulates that plant protection may only be carried out in accordance with good professional practice. The guiding principle here is integrated plant protection that, in accordance with Sec. 2 of the PflSchG, comprises "a combination of procedures in which the use of chemical plant protection products is limited to the absolutely necessary extent, with priority being given to biological, biotechnical, plant breeding and technical cultivation measures". However, the system is dependent on crop rotations not being planned too closely and that fallow land, verges and hedges exist in the agricultural landscape. It therefore depends on the development of a near-natural relationship between pests and beneficial insects (see paragraph 22). Otherwise, weed and pest infestations can only be solved by chemical applications. In principle, plant protection products legislation therefore requires sustainable crop rotations and sufficient structures in the landscape. However, there is a lack of consistent enforcement and appropriate legal interpretation of the obligations of the farmers to prevent pest infestation. The provisions of § 2 of the PflSchG could be substantiated by the responsible authorities through a specified proportion of fallow land and small structures as well as obligatory extended crop rotations. On the one hand, this would lead to higher costs and reduced yields. On the other hand, with appropriate management, the strengthened self-regulatory forces generated by biological pest control and improved soil fertility would contribute to reduced inputs, leading to savings (FIRBANK et al. 2003). Through a higher proportion of fallow land and small structures, such as hedges, verges and flower strips and extended crop rotations, many other living organisms of agricultural biodiversity, such as birds, are also directly or indirectly promoted (VICKERY et al. 2009). In order to promote the implementation of integrated pest management, advisory services should be improved and the development of selective, practice-oriented methods of biological pest management promoted. These measures for broad implementation of integrated cultivation could thus not only contribute directly to insect protection and the implementation of the Federal Government's biodiversity strategy; they would also support the objectives of organic farming, the implementation of the Water Framework Directive and the commitments to the biotope network.

Remedy deficits in authorisation procedures for plant protection products with regard to risk assessment

62. The approval of plant protection products active substances and the authorisation of their products are preceded by a comprehensive environmental risk assessment. In Germany, the Federal Office of Consumer Protection and Food Safety is the central approval authority for plant protection products and the Federal Environment Agency (UBA) is the regulatory authority for the assessment of environmental risks. However, this assessment has shortcomings. For example, test organisms used in the laboratory have proven to be less sensitive to exposure to certain pesticide active substances than naturally occurring species. Similarly, indirect effects still receive too little attention (see also SRU 2016, paragraph 449 et seq.). In addition, the approval is reaching its limits because it cannot reflect all harmful effects on biodiversity at reasonable cost (SRU 2016, chapter 6). These shortcomings must be addressed by the continuous development of risk assessment, e.g. the consideration of particularly sensitive (wild) animal and plant species and combination effects (SCHÄFFER et al. 2018). However, due to their focus on the individual products and their respective applications, the risks of the integrated pesticide use cannot be fully assessed. For this reason, only a minimum standard of protection can ever be guaranteed within the framework of the approval process, so that further measures to reduce the risks of plant protection products beyond the approval process are indispensable. The possibilities of authorisation practice, including rules of use and conditions, must be used to prevent unacceptable effects of the use of plant protection products. Conditions of use may also include, for example, the provision of compensation areas. A study commissioned by UBA proposes to offset the loss of biodiversity caused by the use of plant protection products with compensation areas of the size of at least 10% of the area of application. This value is based on studies on birds and mammals. Comparable data for insects are not yet available (HÖTKER et al. 2018).

The effects of the use of plant protection products should be monitored in order to be able to adapt the authorization conditions if necessary (SCHÄFFER et al. 2018).

4.1.4 Reducing nutrient inputs

Stringent enforcement of amended fertiliser legislation

63. The excessive input of reactive nitrogen compounds, especially from agriculture, is a persistent environmental problem and contributes to the loss of insects in various ways (Sec. 3.2.2). The central instrument for the reduction of nitrogen and phosphorus inputs from agriculture is the Fertiliser Ordinance, which was amended in 2017. It must now be strictly enforced in order to achieve the environmental quality objectives for surface water, groundwater, air and biodiversity (see also SRU 2013). In addition, the Fertiliser Ordinance must be evaluated at an early stage with regard to its environmental impact and, if necessary, improved.

64. The stricter requirements in the Fertiliser Ordinance will lead to an increased transport of farm manures such as liquid manure, slurry, manure and fermentation residues, which makes sense if this replaces mineral fertilisers (SRU 2015). However, this must not lead to higher nitrogen surpluses in the receiving regions, which have more negative impacts than in the region of origin, for example in regions with less favourable site characteristics or in the vicinity of sensitive ecosystems, such as naturally nutrient-poor grasslands or water bodies.

65. In order to achieve the necessary reductions in nitrogen inputs, the SRU advocated in its Special Report "Stickstoff: Lösungsstrategien für ein drängendes Umweltproblem" in 2015 the introduction of a levy based on the nitrogen surplus of the individual farm in addition to the regulatory law (SRU 2015). The levy would create an incentive for farmers to reduce the overall level of emissions cost-effectively and beyond the regulatory requirements. Once the administrative costs have been covered, the SRU believes that the funds collected should flow back into the agriculture sector, for example in the form of advisory services, the promotion of technical measures to reduce emissions or management measures in sensitive natural areas.

Establish ambitious nitrogen reduction programmes

66. The reduction of nitrogen emissions should be integrated and coordinated. In its nitrogen report from 2017, the Federal Government developed a common understanding of high nitrogen inputs as a pressing environmental problem (BMUB 2017). However what is lacking is an ambitious action programme that is developed and implemented in cooperation between various departments and has a long-term focus (see also SRU 2015).

Also important in this context is the national air pollution control programme, which the Federal Government must draw up by the end of March 2019 (Paragraph 38). It must set out the measures to be taken to reduce ammonia emissions by 29% by 2030. It is foreseeable that this reduction obligation cannot be met with the measures currently in place or already adopted. It is therefore urgently necessary that at least the above mentioned measures to reduce the use of nitrogen (Paragraph 63 et seq.) are implemented. The Federal Government's nitrogen report should therefore be accompanied by an ambitious action programme and the measures set out therein should also be used to shape the national air pollution control programme in such a way that the reduction obligations for ammonia are safely met by 2030.

4.2 Strengthening existing protected areas

67. Protected areas under the Federal Nature Conservation Act provide legal protection for areas of particular ecological value. As remnants of natural or semi-natural habitats, they are important refuges not only for many endangered species. It is therefore all the more alarming when even in these protected areas insect populations decline dramatically and protected areas can no longer fulfil their function. Many of these areas are in poor ecological condition and often show a negative development (BfN 2014b). Substance inputs are a major cause of this. Therefore, the use of fertilisers and pesticides in these areas must no longer be permitted (SRU 2016, chapter 6). The legal basis for this is provided by the Plant Protection Framework Directive 2009/128/EC. According to Art.12(B) of this Directive, the Member States shall ensure that the use of plant protection products in protected areas under the Birds Directive and the Habitats Directive is minimised or prohibited as far as possible. Conservation concepts for protected areas should be optimised with regard to habitat requirements and life cycles of insects, unless other protection objectives stand in the way.

In addition, extensively managed buffer zones should be established around protected areas to shield from undesirable external effects, in particularly those arising from agricultural activities such as pesticide drift during application (BENNETT and MULONGOY 2006, P. 7). Depending on the use and structure of the surrounding landscape, buffer zones may be of particular importance, for both protection and acceptance of the protected area. However, the establishment of such zones requires that agricultural areas be made available for this purpose (SRU 2016, chapter 5).

4.3 Further reducing land use for housing and transport

68. The use of land for housing and transport is associated with many negative impacts on biodiversity, and thus also on insects (SRU 2016, chapter 4). In addition to the direct loss of habitats for insects, the space and food supply and light conditions in the neighbouring areas are also changed. Furthermore, the fragmentation of the landscape due to the barrier effect of traffic routes leads to the prevention of migratory movements and the isolation of populations. As land use for housing and transport increases, so does the pressure on the remaining area, both for agriculture as well as for protected areas.

69. The SRU regards land certificate trading as a promising instrument for reducing land use (SRU 2016, chapter 4). The concept envisages that cities and municipalities will be allocated certificates that they need in order to be allowed to build on the outskirts of built-up areas. Unused certificates can be traded. To this end, the "30 ha minus x" target of the German Sustainability Strategy should be operationalised in the form of a quota system. In order to effectively limit the redesignation of building and industrial areas, the provision of Sec. 2 Paragraph 6 Clause 3 should also be filled with life through quantified specifications in federal state and regional planning for land designation. The aim should be to reduce land use to net zero by 2030 (ibid.). Unfortunately, in the new edition of the German Sustainability Strategy 2016, targets for loss of open space as well as targets for settlement density were added, but the land use target of "30 ha minus x" by 2030 was not further developed (Federal Government 2016).

4.4 Reducing negative effects of artificial lighting

70. In order to reduce the negative effects of artificial lighting, there are a number of approaches with regard to technology, behaviour, law and research (HELD et al. 2013; GESTON et al. 2012). The relevant standard for street lighting, DIN EN 13201, contains only minimum and no maximum values for lighting. It should be adapted to reduce the negative effects on insects as well as on human health. Street lighting should be based on the minimum values required for safety. In addition, artificial lighting should generally be used as little as possible. In the interest of insect protection, luminaires should be sealed to prevent insects from entering and should radiate downwards. Warm white LEDs without UV and blue components have proven to be the most insect-friendly light sources, as they have the lowest attracting effect (EISENBEIS 2013). In their principles and specifications for public lighting, local authorities are increasingly taking ecological concerns into account, alongside safety aspects. However, the focus is primarily on energy efficiency, not least because of the EU Ecodesign Directive 2009/125/EC. The Federal Government and the Federal States should therefore adapt the existing funding programmes (e.g. the "municipal climate protection", a federal funded programme) so that, in addition to energy efficiency, aspects of insect protection are also taken into account. This is also important since the conversion of such systems involves long-term investments. The public sector should live up to its role model function. A guideline with recommendations regarding lamp design, orientation, lighting intensity, colour temperature, etc. would be valuable. By providing information and creating incentives, the effects of artificial lighting on insects should also be reduced in the private sphere. In addition, low-lit areas such as "starry star parks", which are characterised by a natural night landscape whereby stars can be seen better, should be promoted. Further research is also urgently needed in the field of light pollution.

4.5 Substantially develop insect and biodiversity monitoring

The situation of insect and biodiversity monitoring

71. Environmental monitoring makes it possible to identify problems (at an early stage), test the results of models and forecasts in reality and evaluate the effectiveness of political measures as well as the efficacy of protection and management measures. Comprehensive national monitoring of species diversity beyond indicator and FFH species is also, but not only, urgently needed for insects. In Germany, there is currently no monitoring system that comprehensively depicts the state of biodiversity and enables comprehensive statements to be made (SRU 2012, chapter 10). Consequently, in its conservation campaign in 2015, the BMU already set itself the task of "expanding, harmonising and coordinating the existing monitoring system with the Federal States in such a way that current questions on the state and development of biological diversity in Germany can be answered reliably in the future" (direct translation) (BMUB 2015). Both, protected areas and the normal landscape, such as agricultural and forestry land, water bodies and settlements must be continuously monitored. The establishment of a scientific monitoring centre for biodiversity as agreed in the coalition agreement is explicitly welcomed (CDU, CSU and SPD 2018, P. 137).

Cross-media monitoring is required in order to link influences of use, material loads and the effects of climate change with data on insects and biodiversity in general (SRU 2012, chapter 10). It should also take into account the development of landscape structures and infrastructure on biodiversity. It is important not only to consider the effects on insects in terms of nature conservation, but also to keep in mind the possible effects of insect pests on human health and on agriculture and forestry. In addition, there are the regulating ecosystem services provided by insects, such as pollination and natural pest control in agriculture and forestry.

In accordance with the various responsibilities, numerous governmental activities already exist in biodiversity monitoring, both at Federal State and state level (MARQUARD et al. 2013; GESCHKE et al. 2017). These form an important basis for further development and supplementation with regard to insects. For example, the Federal Agency for Nature Protection, together with various partners, has developed and implemented monitoring in accordance with the FFH Directive (including recording of the insect species in the appendices), the voluntary breeding bird monitoring, coordinated by the Dachverband Deutscher Avifaunisten (DDA) [Umbrella organization of German Avifaunists], and the High Nature Value HNV farmland-monitoring. These already allow statements on the condition and change of biodiversity to be made for their focal points. Breeding bird monitoring and HNV farmland monitoring already use representative sampling areas nationwide (BfN 2018b).

In the NAP (Paragraph 57), the Federal Government and the Federal States have committed themselves to establishing a framework concept for monitoring small water bodies in agricultural landscapes, the design of which is currently being worked on (BMEL 2018b). This programme is supplemented by the SPEAR index (SPEcies-AtRisk index) (ibid.), which can provide information on the extent to which macro-invertebrates in watercourses are endangered by the use of insecticides (BRINKE et al. 2017). In addition, the Johann Heinrich von Thünen Institute (TI), together with the Julius Kühn Institut (JKI) and the Federal Office for Agriculture and Food (BLE) is currently further developing monitoring approaches and biodiversity indicators for open agricultural landscapes and areas used for agriculture (DAUBER et al. 2016). In order to be able to take account of Germany's diversity of agricultural areas in a concrete implementation of biodiversity monitoring in the agricultural sector, TI, JKI and BLE are developing a characterisation of agricultural landscapes in Germany. For these, it will then be possible to coordinate and define guiding principles and biodiversity targets specific to the respective agricultural areas, for which in turn relevant sets of indicator can be tested and used.

Furthermore, science has also made substantial contributions in recent decades, both at the conceptual and methodological level as well as at the implementation level (MARQUARD et al. 2013; GESCHKE et al. 2017). Non-governmental actors also play an important role in monitoring and must be actively involved in the further development of nationwide monitoring. Volunteers make a significant contribution to the above-mentioned bird monitoring and other activities (cf. paragraph 81).

In addition to the monitoring activities mentioned above, there is also a wide variety of valuable data sets from science and public projects. These were originally not collected for monitoring, but can be used for this purpose. Concepts for access to and handling of such heterogeneous biodiversity data have already been developed by a consortium financed by the Deutsche Forschungsgemeinschaft e.V. (DFG) [German Research Foundation] (GFBio, not dated). However, the use of the developed data structures, workflows and services lacks continuity and an obligation to feed in data from publicly funded projects from research and practice.

While there are already numerous coordinated activities for the monitoring of individual species, species groups and habitats (such as agricultural areas, FFH species, FFH habitat types and birds), the monitoring of insects in particular poses special challenges due to the diversity of the insect groups to be assessed and thus also with regard to organisation and workload. So far, only selected species groups, such as butterflies, have been assessed comparatively well (cf. paragraph 81; UFZ 2018). There are only individual, locally restricted programmes such as the work of the Entomological Association Krefeld e.V. as previously mentioned (paragraph 13).

Integrating existing activities and merging them into one monitoring centre

72. Bringing together the existing activities associated with different objectives and interests, coordinating them more closely, and extending them to include a substantial insect component must be a key objective for the future nationwide biodiversity monitoring (cf. also BONN et al. 2016). For an insect monitoring to be introduced promptly and coordinated between the Federal Government and the Federal States, it is important to make use of the existing experience gained from monitoring other species groups and their recording methods for insects and, to make the data basis comparable and thus jointly evaluable. In addition, however, it is necessary to bear in mind the special features of recording these diverse species groups, especially with regard to methodology and workload. When developing monitoring programmes, consideration should also be given to groups of insects that may be less conspicuous, but which perform important ecosystem functions (e.g. parasitic species, destructors). With regard to further integration with ongoing biodiversity monitoring activities, insect monitoring should use the existing representative sample areas. It should be designed to cover all habitat types so that, similar to bird monitoring, statements can be made for different habitats. The establishment of nationwide insect monitoring should begin in this legislative period.

73. A nationwide (science-based) monitoring centre should subsequently be designed in such a way that it can record and document long-term trends. The existing activities, including insect monitoring, should be more integrated, the further development of new (technical), cost-effective recording methods and evaluation procedures should be supported and their implementation coordinated. The aim should be to enable both, the recording of status and trends in population development and the connection with the possible causes for their changes and important stress indicators. Data already available in research and practice must be better recorded and integrated into the new centre's database.

To this end, the Federal Government should bring together all actors from public authorities, science and civil society as soon as possible. The first step is to develop a governance structure that combines the necessary political objectives of monitoring with the actors involved in implementation and the broad scientific expertise available in Germany. Continuous funding must be ensured and the structural question of responsibilities between practice and research must be overcome. Finally, international developments in biodiversity monitoring at EU level and within the framework of the CBD should also be taken into account so that the German approaches will be compatible with the international monitoring (cf. e.g. the work of the Biodiversity Indicator Partnership (BIP) or the development of the Essential Biodiversity Variables (EBVs) within the framework of the Group On Earth Observations Biodiversity Observation Network (GEOBON)).

The establishment of the monitoring centre will also require an assessment of the existing taxonomical expertise in Germany: It will be necessary to invest more in the relevant training in species knowledge, conventional taxonomy and systematics (paragraph 75) and in modern recording and analysis methods such as genetic barcoding, automated recording methods, modelling and modern statistics for trend analyses (Leopoldina – National Academy of Sciences 2014).,

4.6 Closing knowledge gaps

74. In addition to the need for further research to further develop monitoring, various fields are emerging in which there is still a considerable need for research on insect ecology, their functions in ecosystems and their response to various pressures from environmental changes. This also includes the various agricultural practices and their effects on insects. The role of light pollution in the decline of insect has already been mentioned, but also other factors are still largely unexplored. The effect of chemical stressors and climate change on the abundance and distribution of insects should also be further investigated. It will also be important to analyse the various threats in combination with each other in order to better understand how their interactions affect insects. Better hazard analysis, coupled with improved monitoring, will also help to further develop the Red Lists for insects.

Furthermore, there still remain major knowledge gaps regarding the functions of insects in ecosystems, such as their role in soils and how they affect insect pests. The impact of insect decline on food webs, for example, also needs further clarification. As part of biodiversity research, the work on such questions should be comprehensively funded and systematically structured, similar to climate research, commensurate with the high significance of the risks of biodiversity loss for humans and other living creatures. Although some progress has been made in recent decades, for example through the establishment of several research centres and networks. Nevertheless, there is still a need for newly established funding programmes that are coordinated across ministries and for the further strengthening and coordination of institutional research across funding agencies.

4.7 Strengthening education, training and continuing education

75. In recent years, the "erosion of species experts" has increasingly become a problem for nature conservation and water protection. Especially for species-rich and difficult to determine groups such as insects, there are sometimes only a few experts (e.g. taxonomists). Some animal groups, such as beneficial insects among parasitoid insects or dipterans, have not been sufficiently researched due to a lack of specialised taxonomists. Nature conservation authorities, planning offices and nature conservation associations are already feeling the effects of this deficiency and have difficulties finding adequately trained staff (FROBEL and SCHLUMPRECHT 2016). This situation is alarming against the background of the current and growing need for experts. In order to implement legal requirements such as the FFH and Water Framework Directives or to carry out environmental impact assessments, but also for social discourse on the value and conservation of biodiversity, sound species knowledge is indispensable (JEDICKE 2010). The reduction of taxonomy in university curricula is considered to be a fundamental problem. However, too little knowledge of the species among teachers at schools and too few opportunities for children and young people to experience nature and to develop a relationship with it are also described as deficits (FROBEL and SCHLUMPRECHT 2016). In addition to species knowledge there is an urgent need to deepen knowledge about the causes of species extinction and appropriate strategies to protect insects.

76. The loss of biodiversity makes the conservation and transfer of knowledge about species and the methodology of addressing and recording an urgent requirement. This applies in particular to the loss of insects, many of which have been poorly researched and tend to be quite inaccessible to the general public. An exception to this are groups that are most likely to be relevant to planning and that are "optically attractive", such as butterflies, wild bees and dragonflies. Taxonomic education and field ecology at universities should therefore be maintained, promoted and qualitatively improved. The topic of biodiversity in general, and entomology in particular, should be included in the curricula of other courses of study, as far as this has not yet been done. This applies in particular to university education in agriculture and forestry, including vocational school teachers in the agricultural sector. In addition, it is necessary to improve the training of teachers in species knowledge and excursion didactics, as they have the important role of arousing the interest of children and young people for the topic. The role of the parental home in this respect should also be clearly pointed out (see also paragraph 77, Recommendation for action: Improving communication).

4.8 Improving communication, raising public awareness

Strengthening environmental education in the field of insects

77. The attention currently being paid to the issue should be used to communicate the importance of nature conservation topics in politics and public, even more strongly than before. The Federal Government, the Federal States and civil society are called upon to do this. Actors with a direct link to insect issues (e.g. farmers, beekeepers, gardeners) should be actively involved. The example of the importance of insects for the ecosystem and their functions for humans clearly shows the great importance of biodiversity (IPBES 2016).

These functional relationships – and thus the key role of insects – should be emphasised more strongly in environmental education in order to illustrate the overarching relevance of the progressive loss of this animal class. This is because the quality and quantity of insect loss is an expression of an impoverishing landscape and a warning sign of a further substantial loss of biodiversity. At the same time, however, the topic offers an opportunity to mediate in the repeatedly raised conflict between agriculture on the one hand and nature conservation on the other, and emphasise more strongly the links between intact nature and successful agriculture through the pollination and regulatory performance of an intact insect population.

To this end, appropriate communication projects should be financed by the participating federal ministries, whereby both, existing initiatives should receive additional support and, if necessary, new projects should be initiated through calls for proposals or competitions (incl. pre-funding for concept development). Funding initiatives, some of which have already been in existence for many years, has the important advantage of consolidating or cost-effectively expanding the canon of target groups that often already exist through additional investments. Furthermore, projects should emphasise the communicative perspective and target specific audiences and not be too general.

Sensitising the public about their consumption habits

78. Ultimately, the role of consumer should also be emphasised more strongly in the communication of the topic. Through their purchasing decisions, consumers can significantly support organic agriculture and biodiversity-friendly products in general (WBBGR 2016). By buying food that is actually needed and generally avoiding food waste, consumers can support sustainable production. The demand for products derived from a wide variety of indigenous and seasonal crop species and varieties as well as animal breeds can have an additional positive impact on agricultural production diversity and thus on biodiversity and insect diversity in rural areas. At the same time, private or professional involvement in the sense of insect-friendly planting can be very effective in residential areas as well as in allotment gardens, company gardens, gardens of schools and kindergartens as well as in municipal areas. The effects of intensive night lighting on insects, especially in private gardens and houses, should also be addressed. Various projects and campaigns, such as the "Deutschland summt!" campaign ["Germany is humming!"] which was launched in cities and has since been extended to include rural districts or the "Schleswig-Holstein blüht auf" ["Schleswig-Holstein is blossoming"] Federal State campaign.

79. It should be examined to which extent the state should further promote the labelling of sustainable forms of agricultural production with the aim of having a positive influence on consumers' purchasing decisions. Admittedly, a further increase in the diversity and complexity of product labelling may potentially overburden consumers and thus reduce the effectiveness of labels (SRU 2012, paragraph 220). However, biodiversity-friendly agriculture will not be financially viable in the long-term through governmental subsidies alone. Society must support such agriculture through the price of food and other agricultural products. Approaches in the area of grassland use and dairy farming, such as labelled standards for pasture or hay-grazed milk production, may serve as good examples (WBBGR 2016; 2015). The introduction of a "nature conservation label" for products produced on land subject to agri-environmental measures or contractual nature conservation could also be useful (SRU 2012, paragraph 222).

Creating more spaces for people to experience nature

80. The Nature Awareness Study 2015 (BMUB and BfN 2016) examined the attitude of Germans towards nature, local agriculture and agricultural landscape. A less pronounced awareness of nature and species loss in the agricultural landscape was observed among the group of people under thirty and among the inhabitants of large cities. Surveys carried out as part of the 2014 Environmental Awareness Study by the UBA revealed that nature and the environment are of comparatively minor importance to young people (GOSSEN et al. 2015). The general promotion of the relationship between humans and nature, especially at an early age, is therefore an important field of action to strengthen the population's interest in nature and its conservation. This applies in particular to urban areas in which only few natural elements exist. Here, open spaces (especially green spaces such as parks and gardens) play an important role. These should be available in sufficient quantities (distribution in the urban area, accessibility) and quality (design, plant selection, usability) in cities and ensure that the urban population is supplied with urban nature. This sufficient supply should be defined according to the different ecological, climatological and health functions of open spaces and should serve as a guideline for cities (SRU 2018). In order to promote children's interest in nature and reduce the fear of contact with plants and animals – including insects – areas of nature experience are important from an environmental education perspective and can be supplemented by modern media such as smartphone apps where appropriate (e.g. "Naturblick" [Nature View] app: Stadtnatur entdecken not dated). Undesigned green spaces in the city, which however take into account safety aspects, can function as "wild playgrounds" that allow independent, creative play and physical movement in a natural environment (STOPKA and RANK 2013).

Promoting Voluntary Engagement and Citizen Science

81. Professional insect surveys can be supplemented by Citizen Science projects (RICHTER et al. 2018). In addition to the necessary strengthening of professional taxonomy training, the involvement of volunteers in surveying should therefore also be improved through appropriate training courses and activities. To this end, a stronger network between species experts and other actors is helpful. The in-depth and intensive study of the subject of insects will raise awareness of the importance and endangerment of this animal class. Those involved in such projects can also become important multipliers. A very successful example is the monitoring of butterfly coordinated by the Helmholtz Centre for Environmental Research (UFZ), in which volunteers have been recording butterflies on a weekly basis along standardised routes (transects) throughout Germany since 2005, thus generating valuable population development and trend data (UFZ 2018). The nationwide monitoring of common breeding birds across Germany by the Dachverband Deutscher Avifaunisten e.V. (DDA) and other partners is another prominent example in which volunteers collect data that can be used to make statements for the whole of Germany. Furthermore, targeted training of young volunteers should be developed already at school age.

5 Conclusions

82. Because of the multiple functions insects perform in ecosystems, they are central to the provision of essential ecosystem services, which in turn provide the foundation for human well-being. Therefore, the observed changes in the abundance of insects must be viewed with great concern. The available scientific research and data indicate a significant loss of insects at both species and population level. This is the result of complex, often cumulative factors, whose concrete contribution can therefore not always be precisely determined. Nevertheless, the main causes of insects decline are sufficiently well known to allow immediate action to be taken. The losses in this most species-rich class of all animal groups reflect the loss and general degradation of ecosystems as a result of anthropogenic overuse. It is therefore to be welcomed that the Federal Government has announced its Insect Protection Action Programme. Effective water, air and soil protection is not only necessary for insect protection. At the same time, a strong insect protection programme also has significant synergistic effects, for example with the conservation of biodiversity as a whole, with the protection of water bodies and with the implementation of more environmentally friendly agriculture. In turn, ambitious climate protection is also highly relevant for insect and biodiversity protection.

83. In order to stop the loss of insects, far-reaching, systemic and area-effective approaches are necessary which require measures in various areas (Fig. 9). These measures should be initiated immediately. Priority should be given to making land use more insect-friendly, since agriculture and forestry play a significant role, not least because of their widespread effect on land. At this, the most important measures are the reduction of inputs of pesticides and nutrients, as well as the enrichment of monotonous landscapes with small structures such as hedges, flower strips and verges, the latter especially along water bodies. In order to achieve this, the current reform of the CAP is an essential window of opportunity to strengthen the promotion of biodiversity and to reward nature conservation and environmental protection measures appropriately. The Federal Government should make urgent use of this central strategic decision of the agenda in order to advocate the strengthening of biodiversity conservation at the European level, which is binding both at the international level through the CBD and at a European level through the EU Biodiversity Strategy.

84. These priority measures are complemented by measures in urban areas. Here, the use of pesticides must also be drastically reduced, both on public green areas and in private gardens. Light pollution must be reduced as well. The general public's awareness for the ecological functions of insects, which go far beyond their well-known pollination performance, should be improved and the possible contributions of each individual to solving the problem should be clearly communicated.

By the end of the current legislative period, the Federal Government should design a Germany-wide monitoring system for insects together with the Federal States and start establishing it. At this, different insect orders as well as their development in different landscape types must be depicted. In this way, long-term development trends can be observed, existing monitoring systems for recording the state of biodiversity in general can be further developed and a national centre for biodiversity monitoring can be established.

Knowledge gaps must be closed not only by monitoring, but also by investigating concrete ecological interactions. This applies, for example, to the effects of artificial light sources or the role of climate change on insect populations. The conservation of the biological environment requires research that is comprehensively financed and systematically structured, similar to climate research, and that shares and discusses its results with the public and actively contributes to the debate on measures to protect nature and the environment.

85. Since the involvement of the agricultural, forestry and other sectors is necessary to counteract or reverse the negative developments described above, the relevant ministries of the Federal Government (i.e. the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the Federal Ministry for Food and Agriculture (BMEL) and, in the case of monitoring and research, the Federal Ministry of Education and Research (BMBF)) should jointly launch the Insect Protection Action Programme. A joint coordination structure between the institutions, but also clear responsibilities for the implementation of the individual measures and achievement of the goals set, are paramount. Those responsible and those affected should also be involved in the process at an early stage. The Ministries of Agriculture at the Federal level and the Federal State level have a special responsibility in this respect. Joint, ambitious action would be an important signal that the Federal Government really does take the dramatic developments in insect populations seriously and wants to stop them.

6 Literature

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