Chapter 2

Insect Conservation for the Twenty-First Century

Michael J. Samways

Additional information is available at the end of the chapter

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Abstract

Insects have been immensely successful as an animal group. They dominate compositional diversity of all but the saltiest and coldest parts of the planet. Yet today insects are declining at a precipitous rate. This is of great concern in terms of impoverishment of Earth, and is also dire for us. Insects contribute to the maintenance of terrestrial and freshwater systems, their service delivery and their resilience. The meteoric impact of humans is challenging this dominance, yet so few people realize that the very fabric of life on which they depend is being unraveled at an alarming rate. Action is required, as are new perspectives, if we are to maintain insect diversity and services through the twenty-first century. Here, we review how we should view and act to have more effective insect diversity conservation based on six themes: (1) philosophy (establishing the ethical foundation), (2) research (the finding out), (3) policy (the framework for action), (4) psychology (understanding how to engage humans in insect conservation action), (5) practice (implementation of action), and (6) validation (establishing how well we are doing at conserving insects). We then overview some emergent challenges and solutions at both the species and landscape operational levels in agricultural, forestry, and urban environments.

Keywords: insect conservation biology, insect species conservation, insect diversity, insect services, conservation strategies, caring for insects

1. Introduction

We live in a rapidly changing world. Yet the very fabric of life on which we depend is in jeopardy [1]. A major component of this fabric is the insects. Although they are small and rarely seen performing their myriad activities, they are critically important for maintaining the world as we know it [2]. They perform so many tasks that life without them would be a catastrophe. Yet, so few people even begin to realize just how important insects are in our everyday lives.

The aim here is first to overview insect success as the dominant organisms on the planet. Then, we focus on the threats that insects are currently facing as a result of human activity. Yet, time is short for us to do something about the escalating insect losses across the planet [3, 4].

While strategies are already in place for undertaking insect conservation, some are emerging as being crucially important for successful insect conservation into the twenty-first century, and beyond. We do this here by overviewing some emergent themes on which to base strategies for averting further insect losses. This is important, as insects are fundamental to terrestrial and freshwater ecosystem processes, and we need to maintain insect diversity for future human generations to appreciate, respect, and rely on for supplying essential services.

2. Insect success from a conservation perspective

Insects are the most speciose organisms on earth, making up 70% of all organisms. They dominate all but the coldest and saltiest environments. They inhabit deserts to tropical forests, and swampy pools to pounding waterfalls. They are the majority that few of us see, hidden in plain view. All terrestrial and freshwater plants, even mosses and liverworts, have associations with insects. Most plants have flowers, and their reproduction depends on insect visitors to pollinate them, and so reproduce. Virtually, all frogs and lizards need insects to sustain them. Well over half of all fish, birds, and small mammals require insect food. In turn, a third of insects eat other insects. In short, insects are the fundamental woof and weft of all land-associated ecosystems. Furthermore, we cannot live without them, as a third of our food, and especially the most nutritious components of our food, such as fruit and nuts, depends largely or totally on insect pollination.

Insect success has come about largely through the insect's body plan, with its three tagma (head, thorax, and abdomen), its immensely versatile skeletal structure, and highly varying physiology. The head is packed with a huge array of sensory apparatus. The thorax has highly effective legs for many environments, and, most notably, wings for dispersing and rapidly finding resources and mates. In turn, the abdomen, houses diverse digestive tracts, as well as reproductive apparatus that in some species produces millions of eggs. Indeed, reproductive potential can be extraordinarily high. Richard Harington calculated that when a gravid aphid is left to reproduce with no mortality, after 1 year, the earth would be covered 14.7 km deep in aphids!

Insects have a wide range of mouthparts molded from the robust chitin of the skeleton, so that they can chew, rasp, suck, and burrow through all sorts of organic tissue, living and dead, plant, animal, and fungal. They are also able produce an immense array of chemicals for attack, defense, camouflage, mate attraction, and digestion. Furthermore, their sensitivity to certain chemicals can be extraordinary, with some moths being able to detect a mate many kilometers away, and others, such as certain parasitoids, able to detect prey deep in plant tissue.

Insects are not just items, but also interactors. They are among the most ecologically connected of all organisms. A simple biotope with just 1000 species, leads to half a million potential interactions. This means that the over 1 million described insect species and the likelihood that there are about 5 million species in all, suggests that insects interact with virtually every component in the terrestrial and freshwater realms (**Figure 1**).

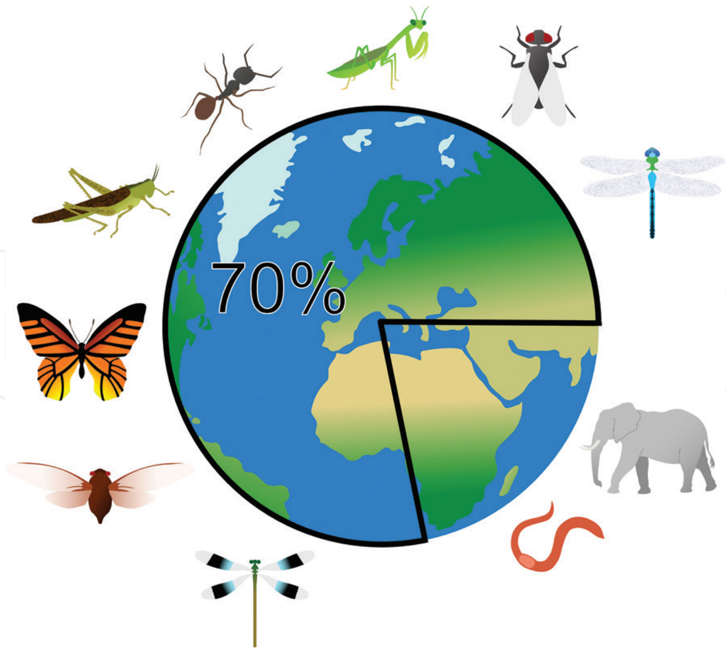

Figure 1. 70% of the species on Earth are insects, despite the land covering only a third of the planet. Insects in terrestrial and freshwater systems are the most highly ecologically connected of all organisms.

3. Insects in today's world

The world is in trouble, with the "World Scientists' Warning to Humanity: A Second Notice" [5] having been issued. We must act now, and decisively, on how we manage the planet. The Anthropocene ("age of humans") is well-established as the new geological era, and the sixth mass extinction is upon us [6]. Insects are central to how we react to this crisis, and how we should respond, as avoiding general ecocide in the twenty-first century rests on involving insects in the new world view.

What is of great concern is that insects appeared to have pulled through the last great extinction at the end of the Cretaceous, 66 million years ago, largely intact [7]. They also survived the various glacial maxima and minima by moving around to re-establish in thermal optima, and to some extent, independent of plants [8]. Such large-scale movement is not so feasible today. The human-induced patchwork of anthropogenic, novel ecosystems has created a myriad of barriers to free movement. With global climate change and landscape fragmentation being a "deadly anthropogenic cocktail" [9], the future for insect diversity depends on three options: (1) adapt on site, (2) move across the human-instigated barriers, or (3) die out. As (3) is not an ethical or survival option, either for insects or us, we must find ways that enable insects to survive through the twenty-first century and beyond.

Despite the importance of insects, it is only relatively recently that they have been mainstreamed into biodiversity conservation. This is being done at various operational levels from the species level through to the landscape level of conservation, with major decisions being made at the scale of nation states through National Biodiversity and Strategy Action Plans. Furthermore, as there are now global insect conservation initiatives, it highlights the adage

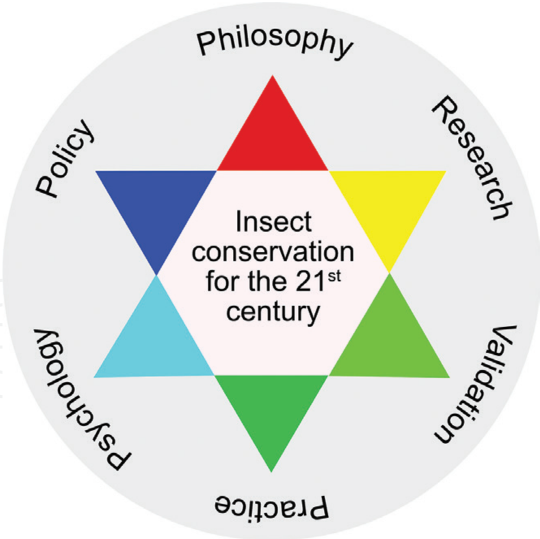

Figure 2. One way to view insect conservation into the twenty-first century is to focus on six, inter-related themes: philosophy, research, policy, psychology, practice, and validation.

"think global, act local." These operational levels, species, landscape, national, and global, are not mutually exclusive, but complementary.

Insect conservation in the twenty-first century can be seen against six inter-related themes: (1) philosophy (establishing the ethical foundation), (2) research (the finding out), (3) policy (the framework for action), (4) psychology (understanding how humans engage in insect conservation action), (5) practice (implementation of action), and (6) validation (establishing how well we are doing at conserving insects). We will now interrogate these themes in more detail. We do this against a background of species, landscape, national, and global operational levels, so as to move quickly to save the current insect diversity on Earth (**Figure 2**).

4. Philosophy for insect conservation

The starting point for insect conservation is to question why we should do it. Arguably, as extinction is the norm, with 99% of all organisms on earth having gone extinct from natural causes, perhaps we should just let events take their course, as a part of an evolving planet? There are two aspects here that we must consider to counter this view. First, there is the intrinsic value of insects, and that they must be conserved for their own sake, especially as they celebrate the immense complexity of life. The argument for intrinsic value is that we are sentient, and hopefully, as we have given ourselves the epithet *sapiens*, a wise and caring species. Quite simply, we share this lonely planet with an amazing variety of life and a stunning selection of insect forms. Are we so crass that we simply send them to oblivion? Second, and quite bluntly and selfishly, they have instrumental value, that is, they have value purely for us. Yet in reality, so few people actually appreciate this value.

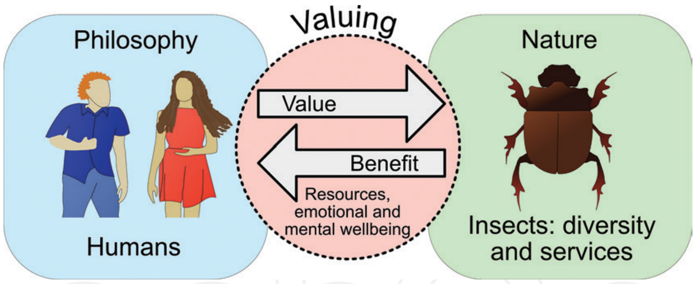

Figure 3. Justifying insect conservation, and then doing it requires a philosophical view based on valuing nature. When value is placed on the human relationship with nature, benefit accrues in terms of physical resources such as food, as well in terms of well-being, both emotional and mental.

With humanity having received its "Second Warning" and global ecosystems in major decline, we cannot carry on as we have been up to now. We require a radical change in thought and action. We need a good philosophical base for steering practice. Many people consider that conservation is instrumental and must benefit humans. This approach stems partly from the logic that by taking this approach, those who hold power will listen. In short, it is considered by many as the only hard currency of insect conservation.

The binary approach of intrinsic versus instrumental value of itself has shortcomings, as it focuses on entities, such as insect species or landscapes, rather than how we relate to nature. There is now a move away from this binary approach to one that focuses on personal and collective wellbeing, based on how we value and relate to nature to achieve this wellbeing [10]. This focus on relational value is built into our need for nature, and that we have a shared destiny, with biodiversity as a whole. This also means relating to insects as most of them are fundamental to our health and happiness, because without them we would have an impoverished and dangerous world as resources decline. Quite simply, we need to look after insects, and they will look after us. We can no longer ignore this fact if there is any future for our grandchildren (**Figure 3**).

5. Research needed for twenty-first century insect conservation

5.1. Operational levels of insect conservation research

Research is concerned with discovery of new information. For insect conservation, this research is about finding new and effective ways for maintaining insect diversity, insect species, and insect populations. As insects are embedded in the ecological fabric around them, and we need to understand it if we are to provide realistic insect conservation solutions, we research the optimal environmental conditions that enable insect survival. These environmental conditions may be abiotic, such as temperature regimes, fire frequencies and intensity, rainfall patterns and intensity, insolation, elevation, rockiness, water, pH, dissolved oxygen, as well as contaminants, pollutants, pesticides, and many others. Environmental variables are also biotic, including vegetation structure and composition, pollen and seed availability, fungal presence vs. absence, host availability (vertebrate or invertebrate, including other insects), mutualist presence, dung availability, mimic models, and so on.

As many insects express developmental polymorphism, where for example, the larva is morphologically and functionally very different from the adult, they may require a host of abiotic and biotic conditions and resources for optimal survival within their habitat. The larva of a butterfly needs a particular host plant(s), as well as enemy-free and disease-free space, while the adult needs certain nectar sources, mate-meeting sites such as hilltops, oviposition sites, sunny conditions for flight, besides enemy- and disease-free space.

Although an insect's habitat is embedded in an ecosystem, some require more than one ecosystem to sustain them [11]. With anthropogenic modification of the landscape, not only are conditions changed within their habitat, but also around it. The landscape matrix around a habitat may not only lack critical conditions and resources, so prohibiting generational survival there, but it also has an effect, often adversely, on the habitat itself. In terms of research, as well as investigating the habitat per se, we also must establish the landscape context and contrast. How we make this matrix more hospitable for insects is a major research thrust in this the twenty-first century. This is where we need to reconcile the needs of insects and those of humans. Progress is being made, but now we must hasten that process in the coming years.

Insects have to move and mate, and so maintain genetic diversity within a species, especially to maintain adaptability to changing conditions induced by humans. Functional connectivity across the landscape that facilitates movement, and so genetic exchange, has become a major challenge for the twenty-first century. Already much progress has been made. This has been done by making the human production landscape and urban environment more insect friendly. This has been done by putting in place stepping stone habitats, while perhaps not being optimal for long-term survival nevertheless provide stop over stations for insects as they move across the landscape, and by instigating conservation corridors, which as well as being for movement, are also source habitats that provide optimal conditions for all the life stages and the production of viable offspring.

5.2. Species-level insect conservation

From a conservation perspective, we can view "a species" as populations made up of a group of individuals. We do not actually conserve "a species" but individuals of the species. Groups of individuals in an overall population do, or do not, exchange occasional alleles. Those that do are metapopulations, and those that do not are subpopulations. Importantly, it is the range of genetic variation in populations and how it is shared among individuals that determines the adaptability of a population to environmental change, whether for the better or the worse, and whether in response to local (e.g., landscape fragmentation, pollution) or global (e.g., climate change) impacts, or both.

The viability of metapopulations depends on the flow of genes that provide high value for adapting to prevailing conditions. These conditions are currently changing rapidly, and are often adversely synergistic, with, for example, fragmentation and insecticidal impact together providing an even greater challenge over the impact of just one. Without gene flow, metapopulation dynamics can be disrupted, leading to an adapt-or-die situation. There might not be enough genetic variation within the isolated group of individuals for survival in the long term, because of changing or stochastic environmental events and/or genetic impoverishment. When populations are isolated by the effect of landscape fragmentation, there may some selection pressure to the new conditions, leading to human-induced evolution, known as anthropovicariance [12]. Philosophically, this leads to an interesting debate. Here, we are not conserving an existing natural phenomenon so much as creating a new one: to what extent is this "new insect" of conservation concern? This sort of philosophical challenge is what we now need to address in the twenty-first century. As novel landscapes (i.e., those created by humans) are now present, arguably we now need to conserve, or at least let live, those species with high adaptive ability, and therefore have an evolutionary future in this rapidly changing world [13].

Subpopulations present a different situation in that they already show some differentiation caused by natural drivers. These different subpopulations are known as evolutionarily significant units (ESUs), each unit of which deserves conservation in its own right. They are in effect evolution in action, and represent new species in the formation. However, some ESUs are threatened and others not. The English Large copper butterfly *Lycaena dispar dispar* is extinct, the Dutch ESU *L. dispar batavus* is highly threatened [14], and the Estonian *L. dispar rutilis* is common and expanding its geographical range [15]. The "species" has been re-introduced and has established in England from Europe, but this is not the original ESU. These are genetic and ethical issues that will confront us ever more this century.

The twenty-first century is likely to see much more focus on the genetics of species, bearing in mind this will always be about a few species attracting special attention. There will be several approaches, and these are already developing. Genetic work has shown that some species are very ancient, with the yellow presba dragonfly *Syncordulia gracilis* having a pedigree going back almost 60 million years [16]. Such species must receive conservation action if we are to show some empathy for ancient insects. Even resurrecting extinct species (revenant species) is feasible from well-preserved specimens in museums [17]. However, this is a lot of hard work for a privileged few in comparison with saving species by good and protective management of natural ecosystems in the first place (**Figure 4**).

5.3. Landscape-level insect conservation

Species conservation is arguably a luxury overlay on insect diversity conservation using landscapes, at least from a global perspective. Insect species conservation is morally right, but exclusive, and time is short for conserving as many insect species as soon as possible. However, there is a good reason to do good insect conservation in parts of the world that can afford that luxury, i.e., in those countries with high GDPs, and where there is great interest and involvement by the public. It leads to exploratory techniques and methods that we will, in the future, need globally. Meanwhile, for those countries with lower GDPs, as well as the more economically developed nations, conserving good quality landscapes with high habitat heterogeneity will not only conserve many insect species and their interactions all at the same time, but also will conserve many insect services to which the public and policy makers can both literally buy into.

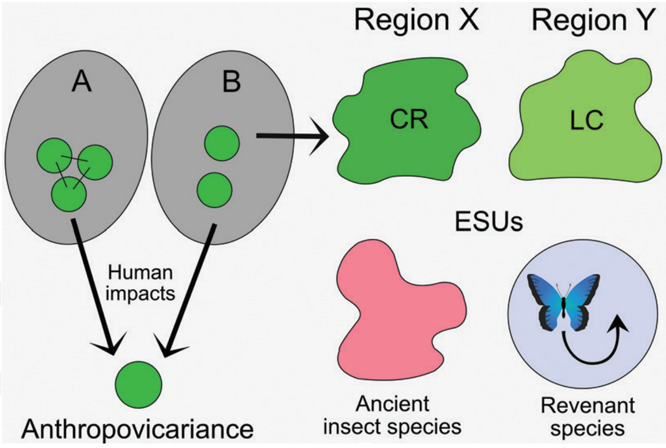

Figure 4. There are great opportunities for insect species-level conservation, as long as we have a good understanding of what "a species" stands for, based on genetic, behavioral, and ecological knowledge. Here (upper left) are two species (A and B), one (A) with populations that experience genetic exchange (metapopulations), and one (B) that does not (having two subpopulations). Either of these might undergo genetic change in response to human impacts, a phenomenon known as anthropovicariance (bottom left). Two subpopulations may be genetically, and usually morphologically, different, making up two evolutionarily significant units (ESUs) in two geographically distinct regions (X and Y) (upper right). The one on the left is red listed as critically endangered (CR), and of great conservation concern, while the one on the right is red listed as least concern (LC), which means that it is not of immediate concern, but it could always be threatened in the future. Ancient species, with a long phylogenetic pedigree, are often of high conservation significance as they are usually genetically highly irreplaceable (bottom middle). A revenant species is one that is extinct as a species and has been brought back to life from good quality genetic material extracted from museum specimens (bottom right).

Conceptually, we as humans relate to landscapes very well, as they fit comfortably into our frame of reference about nature. We see this already with the evolution of new perspectives. While there has been much progress in the past with species conservation, there is now a shift towards viewing nature as a vast array of benefits that it provides, which includes being in nature for our wellbeing.

Natural England's Conservation Strategy for the twenty-first century [18] articulates this well, and uses three guiding principles: (1) creating resilient landscapes (and seas), (2) putting people at the heart of the environment, and (3) growing natural capital (i.e., giving populations the chance to survive and increase). The earlier strategy of ring-fencing and protecting individual species and habitats has not been successful, having led to local species loss. The focus now is at the larger spatial and conceptual scales, with the development of resilient landscapes and ecosystems. This has led to research on the drivers of species loss and deterioration of ecosystems vis-à-vis what maintains species, their interactions, and ecosystem function. This means understanding what are opportunities and realistic strategies can be brought into play. These include engaging wildlife-friendly farming, gracing the urban environment with biodiversity-friendly green spaces, and improving functional connectivity across the landscape.

All these biological perspectives must include people and their wellbeing if it is to succeed. The focus moves away from risk toward a new approach that involves enhancing and investing in the environment, leading to long-term stewardship of environmental assets. Interestingly, this new approach does not exclude a species focus, but rather integrates it into a vision of long-term resilience across landscapes. Crucially here, it includes insects of all types, whether

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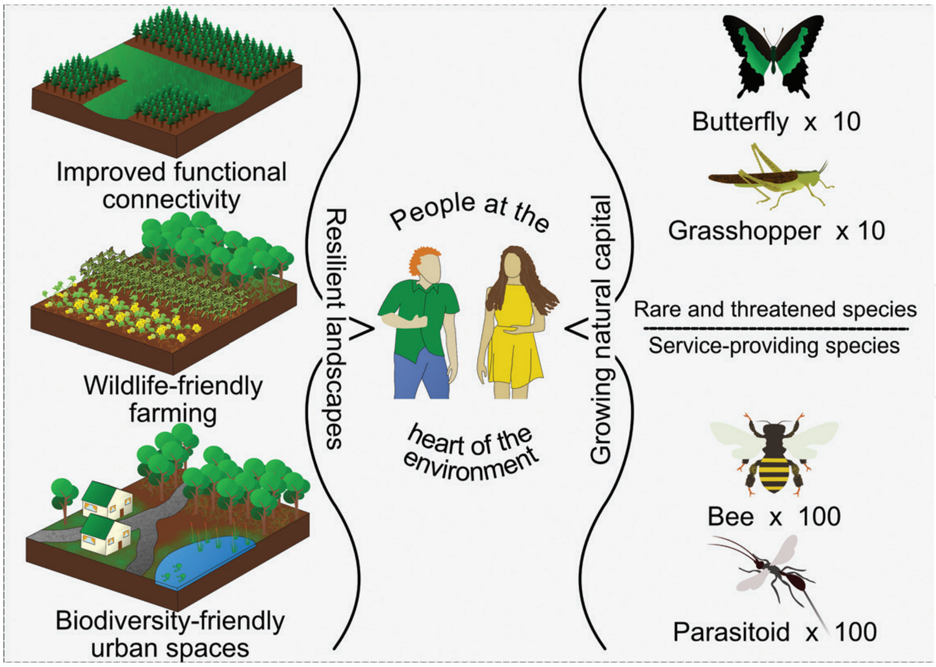

Figure 5. Landscape-level insect conservation based on three guiding principles: (1) creating resilient landscapes, (2) putting people at the heart of the environment, and (3) growing natural capital, as perceived by Natural England. Resilient landscapes include, for example, improved functional connectivity (here, grassland conservation corridors between exotic pine plantation tree blocks, wildlife-friendly farming such as using organic methods and leaving an increased proportion of natural habitat, as well as biodiversity-friendly spaces in the urban environment). Growing natural capital is just not only about improving indigenous species richness, but also improving the abundance of the focal species. In the case of rare and threatened species, an increase of ten times would be a great improvement, while for service-providing species, like bees for pollination and parasitoids for pest control, a 100-fold increase would be truly excellent.

threatened or not, which contribute to a more informed landscape approach. It is essentially a positive feedback loop, with all species, including humans, benefitting. In turn, it is the sensitive species on those landscapes that can tell us how well we are doing. These principles now require more research to tailor them to local circumstances (**Figure 5**).

6. Policy for insect conservation

There are two ways to consider insect conservation as regards policy. Insects are a component of biodiversity, and secondly, they provide essential ecosystem services. These perspectives can be considered at various spatial scales, from global down to national (bearing in mind that nation states are an important conservation action unit), and then local.

From a biodiversity perspective, insect conservation is integral biodiversity conservation, as insects function at various trophic levels, and so interact with many other organisms, plant, fungal, animal, protoctist, as well as among themselves. Biodiversity conservation is globally framed in terms of the Convention on Biological Diversity (CBD), which is agreed to by most nation states. Importantly, the Aichi Biodiversity Targets, under the umbrella of the CBD, provide some specific goals, and with the exception of those specifically relating to the marine environment, apply to insect conservation into the future. There are, however, a few marine insects, notably sea striders (Hemiptera, Gerridae: *Halobates* spp.).

Insects globally are conserved both at the species level and as insect diversity. At the species level, it is the International Union for the Conservation of Nature (IUCN)/Species Survival Commission (SSC) that is the major global proponent through production of the Red List of Threatened Species (www.iucnredlist.org). This globally recognized list provides just not only an inventory of the world's species and their threat status, but also gives suggestions for conservation action. It does this through the activities of a network of specialists on various taxonomic groups.

The red list however, is not a priority list for action, and nor is it a political document stipulating what governments or agencies should do to conserve insects. Quite simply, but importantly, it is an assessment of the conservation status of the insects that have so far been assessed. Nevertheless, it is highly influential for conserving insects globally. One reason for its impact is that once a species is assessed on the red list, and especially when a species in listed as threatened (as opposed to not, i.e., that it is classified as Least Concern), a species tends to become highly iconic. This is a great boost for listed insects, as they then receive the same treatment as a wombat, whale, or weasel. In short, their profile is raised considerably, and so automatically find their way into policy documents on biodiversity conservation.

The greatest challenge, among many [19], for insect species Red Listing is that the group is so speciose, with today only about 7700 species having been evaluated for the Red List, which is 1% of described species, 1,060,704 in all [20], and probably less than 0.2% of the millions that exist. The reason for these low percentages is that considerable field work is required to assess the threat status of an insect species, and there are relatively few insect specialists to do the job. The situation is aggravated by many species going extinct without even having received scientific names, a phenomenon known as Centinelan extinction (named after Centinela Ridge in Ecuador where botanists found many plants had gone extinct from deforestation before they could name them).

Of those insects that have been assessed, it is possible to get a sense of the types of threats facing them. When lumped with terrestrial invertebrates in general, the main threats in decreasing order are: (1) habitat loss due to logging, (2) habitat loss due to agriculture, (3) infrastructure development such as urbanization, (4) habitat loss and fragmentation due to transportation/service corridors, (5) invasive alien species, (6) change in fire regime, (7) pollution, (8) climate change/severe weather, and (9) mining [21]. For freshwater invertebrates, pollution and dams/poor management are the major threats, and greater than all the others together [22]. Knowing what these threats are not only helps us plan for the future, but also bearing in mind that for any one insect species, there may be more than one threat, as threats are often adversely synergistic.

International trade in insect species is regulated. This is done through the Convention on International Trade in Endangered Species (CITES). To date, however, few insect species are listed, and they are mostly large, highly collectable and charismatic species, like birdwing butterflies. Objectively, there should be many more insect species that are CITES listed, but this is not the case because the limited financial resources for doing so are prioritized for restricting trade on charismatic vertebrates and rare plants, which are facing a desperate plight in its own right.

Moving down to the national scale, insect species conservation varies greatly from one country to another, with those countries with a high Gross National Product usually devoting more attention and resources to insect species conservation than the financially more constrained countries. Some countries have strong regulation protecting insects (e.g., all dragonflies in Germany). There are also consortia, and especially notable is the European Union Habitat Directive, where there is co-operation on protecting insects across the continent.

As regards, ecosystem services as defined by the Millennium Ecosystem Assessment [23], insects are highly significant. In terms of provisioning services, they are important as biological control agents of pests, for monitoring ecosystems, as well as for providing new medicines, and acting as tourist attractions in the wild, and in commercial butterfly houses in urban areas. Regulating services provided by insects include nutrient cycling, pollination, seed dispersal, stopping, or slowing invasions by other insects, and contribution to atmospheric gases. They also provide supporting services through breaking down living and dead plant material, as well as turning over soil. In turn, cultural services are many, and include representativeness of the variety of life, connecting with the natural world (especially through children), and use in genetic research.

All these services are often strongly recognized by policy makers, and regularly form the basis of justification for conserving insects, i.e., for what they do for us, which in the USA is estimated to be $57 billion/year [24]. But, we must be careful not to confuse the conservation of insects for the services that they provide with the conservation of insect species, which may not be the same set [25].

With recognition of the value and importance of insects with each passing year, insects are being increasingly enshrined in policy, at least in countries that have great respect for nature and recognize that our survival depends on valuing and conserving them. Recognition of the value and importance of insects will become more important with the passing of time this century.

Insects have been eaten by humans (entomophagy) from the earliest of times, with today an estimated 2 million people eating insects as part of their traditional diet. This is because insects are highly nutritious, being high in protein, essential fatty acids, and in important minerals such as calcium, copper, iron, selenium, and zinc. Commonly eaten insects are beetles, moth larvae, bees, wasps and ants, cicadas and other bugs, termites, dragonflies, flies, as well as some other insects [26]. Entomophagy will become increasingly important in the twenty-first century, both for direct human consumption and for livestock. Entomophagy is also now being used as a way of tackling malnutrition in children [27].

This increased reliance on insects is partly driven by red meat production being three times more resource hungry than insect production. While insects traditionally have been harvested from the wild, there is now a move to rear them on a large scale. This intense farming of insects has challenges, but new rearing and processing techniques and methods will inevitably come about simply because natural habitats are decreasing, and the size and demands of the human population are increasing. Improved insect farming will go hand in hand with new developments in the visual appearance of the food, and its design, so as to make insect food increasingly acceptable to a more discerning human population [28] (**Figure 6**).

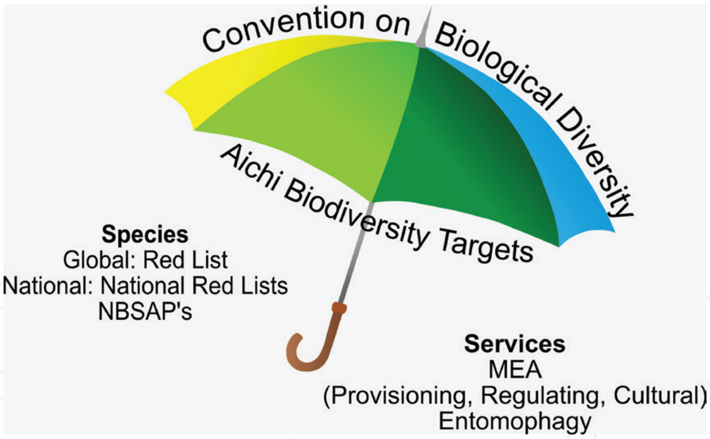

Figure 6. Insect conservation policy has various perspectives. Overarching is the Convention on Biological Diversity to which most countries in the world are signatories. The Aichi Biodiversity Targets, which are specific targets, mostly have great application to insect conservation. In terms of conservation of species *per se*, the International Union for the Conservation of Nature's global red list gives important coverage to insects. At the national level, local red lists (RLs) are important too. National Biodiversity Strategy Action Plans (NBSAPs) are also significant for local insect conservation, especially in biodiversity hotspots. NBSAPs cover a wide range of biodiversity issues and targets besides insect species conservation. As regards services supplied by insects, these may be described under the Millennium Ecosystem Assessment (MEA). It provides a framework to include provisioning, regulating and cultural services. An important service currently being supplied by insects is entomophagy, the human consumption of insects, which is becoming increasingly mainstream globally.

7. Insect conservation psychology

Understanding human behavior, promoting wellbeing, and increasing human care for nature is conservation psychology [29], which recognizes our dependence on nature and an understanding of why and how it is so essential for our wellbeing. Given, the huge role that insects play in providing services of all sorts, insect conservation psychology is going to play an important, if not vital, part in our survival into the twenty-first century [30].

As we advance technologically, we seem oblivious of the collateral damage we are doing to so many other species and their interactions, despite so many warnings that we are vitally dependent on them. In short, we are doing untold damage to the very systems on which we depend, with insects being at the heart of them, at least on land and in freshwater. We simply take nature, and insect services, for granted, and this cannot continue into the twenty-first century without dire consequences. Just as we do not see water vapor coming off plants, or the oxygen being breathed out by them, we just do not see insect diversity and our dependency on it: out of sight, out of mind.

Many of us have great interest and even respect for insects as children. But there are only certain "species," like "the" butterfly, bee, grasshopper, ladybird, and dragonfly that we hold dear. These are the iconic insects that are fascinating to us as children (and adult entomologists!), and are also benign. Only as we grow up, do we begin to realize that "the fly" is dirty, and "the mosquito" is a nuisance, if not dangerous. So, all insects get lumped together in our adult perceptions, i.e., not worthy of our consideration and conservation. This realization is now changing for the better, with the global realization that we have a pollinator crisis around the world, and "the bees are dying" [31]. This has aroused considerable awareness of our dependency on insects.

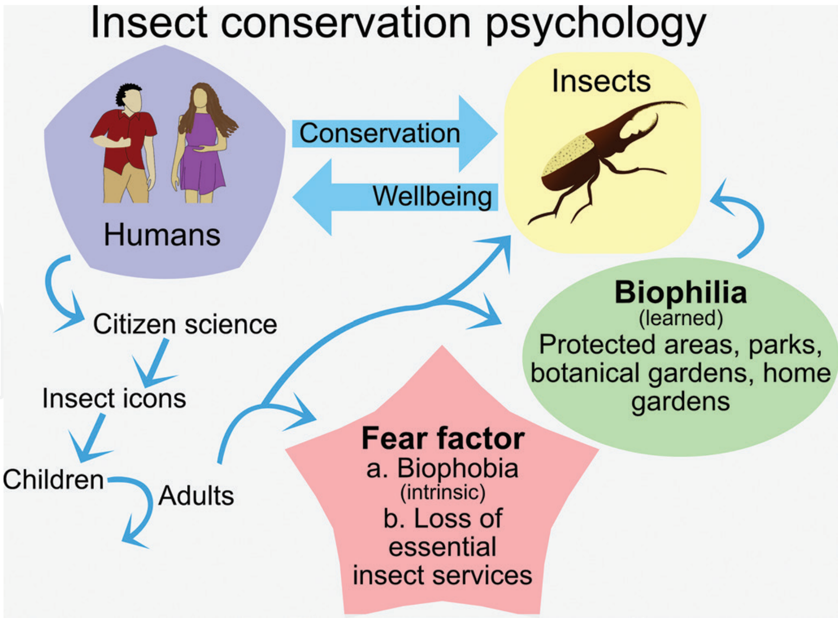

Figure 7. Insect conservation psychology is the relationship between humans and insects. The conservation of insects is essential for our wellbeing. The involvement of the wider body of the public in recording, monitoring, and engaging in conservation is citizen science. This activity promotes wellbeing in people while helping ensure a future for insects. Insect icons like "the bee, butterfly, and ladybird" are highly significant for children, but often we as adults forget them in our preoccupied lives. This is partly because an awareness develops that "the fly and the mosquito" are not good for us. We are also aware that the wasp stings, and so will the bee if we are unkind to it. This is biophobia (a), which is intrinsic to us. Yet when we overcome this fear factor, we culturally develop biophilia, especially when we see the beauty of nature, including insects, in our parks and gardens. Besides biophobia, the fear factor today has a second component, a concern that there is a loss of essential services (b), particularly pollination. Our reaction to this service loss, alongside biophilia for certain species, is feeding back into insect conservation, which, in turn, improves our sense of wellbeing.

It has also dawned on us that we need to be far more aware that widespread use of insecticides is not only detrimental to our health but also undermining our very food base, despite actually having been articulated in the 1960s [32]. The pollination crisis has also led to much action to find solutions to it, and for once, right now without delay [33]. Like climate change, the pollinator crisis is no longer something to think about in the late twenty-first century—it has already arrived with full force.

While our dislike of many insects is intrinsic (biophobia/entomophobia), love and appreciation of insects (biophilia/entomophilia) is learned [34]. This learning can only come about from positive experiences, for example, by seeing insects in their natural environment, whether in the home garden, botanical garden, or protected area. Indeed, protected areas receive 8 billion people visits per year [35], with a profit of $250 billion/year [36], making protected areas, along with other natural areas, good for human wellbeing, while also earning their keep and supporting a vast array of insects.

Linking insect conservation psychology to research and policy can come about through citizen science, the involvement of informed and enthusiastic sectors of the public for recording the distribution of species and engaging in insect conservation [37]. This involvement of the public has greatly improved our knowledge of many insect groups [38–40]. The improvement in knowledge, and hence insight, comes about simply because there are more enthusiastic eyes and hands in the field increasing the amount of information on species, and this can be very high in the case of threatened, red listed species, as well as many others that are not threatened, at least for now. This information then also becomes valuable for lobbying policy makers. Enthusiastic citizen scientists are also making direct contact with policy makers, and therefore increasing the voice of change-for-better in insect conservation. This approach is going to become increasingly important in the twenty-first century (**Figure 7**).

8. Insect conservation in practice

Insect conservation is a practical activity based on good research and a sound knowledge base. The foundation for practice is a well-understood philosophical underpinning, valuable research findings, and then a strategic response to well-informed policy, alongside applied insect conservation psychology. Yet, the practice of insect conservation is rarely actually carried out by philosophers, researchers, policy makers, or psychologists. Insect conservation action is usually carried out by conservation organizations, concerned farmers, and progressive private companies, and other responsible land stewards and owners, all of whom are highly cognizant of philosophy, research, policy, and psychology. It is also carried out by citizen scientists, many of whom may be associated with self-grown non-governmental organizations like the Xerces Society, Butterfly Conservation, and Buglife, who receive donations from private funders, as does IUCN at the global scale. Citizen scientists are usually active in their home area, where they carry out insect conservation activities in addition to monitoring, especially on nominated insect species, and often those of special concern. This is another reflection of the "think global, act local" principle.

There is a baseline for insect conservation that is non-negotiable, that is, the recognition of formally proclaimed protected areas composed of natural habitat. The significance of this is that these areas are often an island in a mosaic of novel landscapes. They are frequently the last bastion for many rare, specialist and/or highly localized endemics, as well as for specialized interactions. As protected areas are usually isolated, they may require some management, usually to mimic the historic condition. Introduction of fire regimes, for example, may be required to simulate the situation before modern human fragmentation of the landscape. Management of fire may be to reduce the fuel load, or so reduce risk of an intense and potentially highly damaging fire, or it may be to stop vegetation succession to an unnaturally woody environment [41].

There are approaches that also intergrade protected areas with the surrounding novel mosaic. Among these are biosphere reserves, of which there 669 in 120 countries, and ratified by the United Nations Educational, Scientific, and Cultural Organization. Biosphere reserves consist of a core and two surrounding zones. The core of the biosphere reserve is fully protected and managed according to historic conditions. Surrounding that is a buffer zone with only low-level human impact on the biota and ecosystem function. Outside the buffer zone is the transition zone, which supports sustainable agriculture or forestry based on agro-ecological principles or organic agriculture, as well as having little infrastructure development.

The transition zone is characterized by low insecticide use, maximal use of biological control, and cultural control measures of pests, low compaction practices (i.e., avoiding heavy machinery),

Figure 8. (Left) An organic vineyard with no insecticide input, mulching of the inter-rows, and the planting of the inter-rows to biodiversity-friendly vegetation. These vineyards are particularly rich in soil fauna as well as in above-ground insect diversity. (Right) Seen here is a large-scale ecological network of conservation corridors of remnant, natural, high value grassland in and among plantation forestry using alien pine trees. These grassland corridors not only conserve biodiversity but also maintain hydrological processes in a natural state.

planting of indigenous flora, and the setting aside of remnant patches as reserves per se or as stepping stones to protected areas. Despite the great importance and high level of instigation of biosphere reserves, there is still little research on their effectiveness for conserving insects and their interactions. Research and validation of these reserves is going to be increasingly important in the twenty-first century, as they may well prove to be a major initiative for harmonizing human activity for optimal production and effective insect conservation (**Figure 8**).

Other insect-friendly approaches are also being used. These go hand in hand with agro-ecological approaches [42]. They follow a spectrum from land sharing (the mixing of crops and insect-friendly plants, e.g., coffee plantations in natural forest [43] to the separation at a larger spatial scale between conservation areas and production areas, known as land sparing (e.g., instigation of interconnected conservation corridors of remnant land to form large-scale ecological networks, e.g., grassland and natural forest patches among plantation forestry blocks [44]. These approaches have been very successful, with ecological networks effectively extending the size of the adjacent protected area and providing much more resilience to the system overall [45].

Originating in Europe, but now more widespread, has been the development of agri-environment schemes, which at the start involved financial compensation to farmers for setting aside land and not cultivate it [46]. These schemes have now grown into fully agro-ecological areas which aim to maximize opportunities for indigenous biodiversity while optimizing production. The aim is not only to conserve insects and other wildlife, but also to promote natural ecosystem services such as pollination and biological control of pests [47, 48].

In general, embracing these new approaches has been beneficial for insect conservation, despite farmers often being concerned that production might dip when moving across to agro-ecological/organic approaches from conventional practices [49]. Nevertheless, the future is looking bright for these new eco-friendly approaches, with increasing global pressure to use farming and forestry techniques that conserve insects and promote human health. These approaches are going to become increasingly prevalent this century. They will be especially effective when high-intensity agriculture is converted into a softer approach, which may require some restoration of both terrestrial and freshwater ecosystems.

Already, more than half the human population lives in cities, with the proportion increasing as the century progresses. There are two fundamental issues to consider: human intensification of the urban landscape, and increasing disconnection between humans and nature. Intensification leads to proportionately less space for nature, and increasing pressures on what remains. Only the widespread generalist insect species will likely survive. As habitat space becomes scarcer, all insects will also be less abundant. Furthermore, there are going to be some major genetic change among those that do not die out.

In this new urban space, there must be provision for all the life stages. While butterfly gardens usually provide nectar for adults, they must, in addition, provide food plants for the larvae. Metapopulation dynamics must also be maintained, and while this may be possible for some species in large urban parks, there will need to be conservation corridors, often known as greenways in an urban setting, to maintain genetic diversity within each species.

Pressures on insect populations in the urban environment are also great [50]. Temperature increase in the urban environment, the heat island effect, presents one challenge. Increased road kill from vehicles and above-ground transportation is another. Pollution is an issue for humans and insects alike. For insects, another major impact is the huge effect of lights, especially on night flying insects.

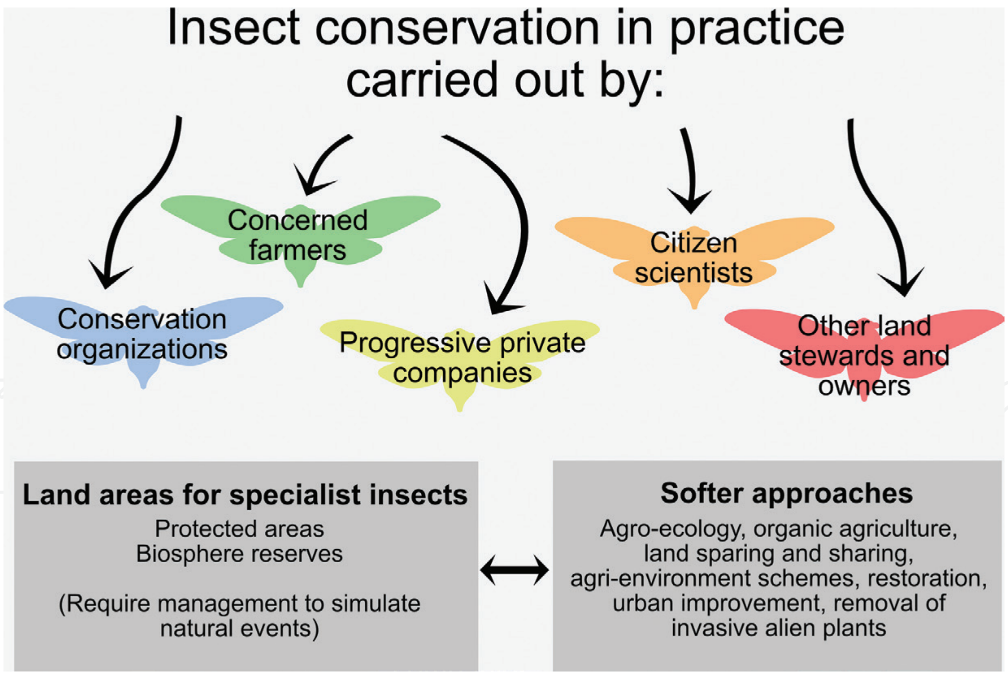

Figure 9. Insect conservation in practice is carried out by various organizational communities. Land cores, such as protected areas and the core zones of biosphere reserves, are critical for many specialist insect species. These areas do, however, sometimes require some management to simulate natural events. Outside of these land cores, softer approaches to landscape design and management take place as insect conservation action. These approaches include agro-ecology, organic agriculture, the land sparing-land sharing spectrum, agri-environment schemes, restoration, urban improvement, and removal of invasive alien plants.

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There are areas of mitigation that are likely to become increasingly important in the twenty-first century. As regards the two fundamental issues, needs of humans as well as of insects, both are inter-twined. Good quality habitat space, terrestrial and freshwater, must be available, and largely populated with indigenous vegetation, and without invasive alien plants. Green walls and roofs are also likely to increase greatly, but mostly as carbon sinks and for esthetics than for native insect diversity. Nevertheless, this would increase awareness and contribute to rescuing the extinction of experience [51], where people, especially children, can stay connected with nature. However, with the increasing devastating impacts of global change leading to more extreme weather events, safety and security must be integrated with an awareness of the plight of insects. However, care for insects is likely to slip down the list of priorities as extreme weather events become more prevalent (**Figure 9**).

9. Validation

Our fifth theme is validation, which links back to the first, research [44]. We need to check how well we have done after we have actually engaged in insect conservation. We measure our insect conservation success by using a range of variables that may be abiotic (e.g., water flow and soil chemistry) or biotic (e.g., plant diversity, plant health, insect diversity, and recovery of insect populations). Before the conservation action, we would have determined the goal. What exactly are we aiming to conserve? Is it a particular species? If so, will it pull through adverse weather conditions? Will it be able to tolerate or move with climate change? Or, we

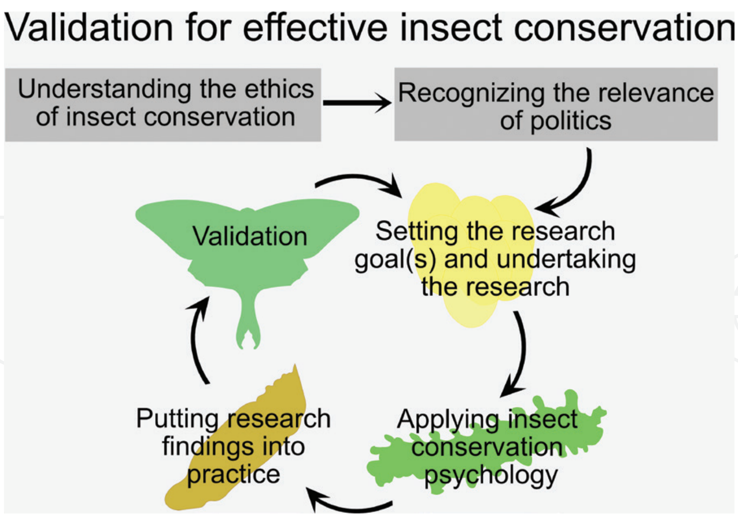

Figure 10. Validation for improved insect conservation means that we have understood the fundamental conservation ethics, and have recognized the relevance of various policies. We then set the conservation goal(s) and undertake the research. We further engage insect conservation psychology as we put research findings into practice. Then comes a critical point in the circle: validation. Here, we ask how well we are doing in implementing research, and whether the conservation practice is effective. If not then we undertake more research. This validation/research/practice cycle is actually never ending, as we must monitor even if we think what we have put into practice is working, as conditions may change, especially given climate change and always the risk of a new stochastic event.

may aim to conserve insect diversity using conservation corridors among plantation forestry blocks. Is the insect diversity the same as measured against a benchmark such as in a nearby protected area? Although species richness may be the same, is the composition the same? Or, when we engage agro-ecology, are the focal services, whether pollination with bees or pest control using natural enemies, being adequately supplied? If so, are the local rare and threatened species also being conserved?

Validation is a circular process: setting the conservation goal, establishing a time line, determining resources to achieve the goal, validating the goal, identifying shortfalls, understanding those shortfalls with research, putting in place a new goal which has then been refined, and so on. In short, as the twenty-first century progresses, we are going to focus more on a healthy and reliable environment, and this is going to require accountability in the form of validation (**Figure 10**).

10. Conclusions

Time is short for conserving the necessary insect diversity to sustain us. Future generations will decry this era of despoliation of the planet, and what we have done to the web of life, including the vast beauty, grace, intricacy, and worthiness of insects. Insects and other biodiversity symbolize this blue and white jewel in an almost incomprehensible vastness of molecular simplicity that we call space. Once the novelty of landing on Mars has worn off, humans will look back at Earth and realize with a great awakening how special it is. This may well (hopefully) trigger a renewed enthusiasm and effort to conserve the great poetry of biodiversity, especially that of insects. It will be a true case of "the grass was not, after all, greener on the other side of the fence."

We are improving our ethical base, but too slowly. We have rapidly increased insect conservation research, but too slowly. We have put in place policy, but acting on it too slowly. We are developing insect conservation psychology, but too slowly. And, as for action, it is being done pitifully too slowly. We are beginning to instigate validation processes, but still too slowly.

We will achieve much insect conservation this century, surfing on the wave of becoming scared of what a terrible mess we are making of the planet and now that our very life base is threatened. We are developing improved range of technologies, from conservation genetics through to satellite technology and information flow, all of which will help us make progress. But we still have to do the physical hard work on the ground to get it all right. The more we live in a virtual world, the more disconnected from nature we will be. We will wake up one day and it will dawn on us that the fiction of money [52] will not sustain us. Nature will always survive, with Conservation International's message "we need nature, nature does not need us" becoming totally real. We will kill many insects, but those which do survive will exist for a lot longer than we will. What saddens me personally is that our grandchildren will say "why did grandpa and grandma destroy so much without thinking of us?"

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Conflict of interest

The author declares no conflict of interest.

Author details

Michael J. Samways

Address all correspondence to: samways@sun.ac.za

Department of Conservation Ecology and Entomology, Stellenbosch University, South Africa

References

[1] Dirzo R, Young HS, Galetti M, Ceballos G, Isaac NJB, Collen B. Defaunation in the Anthropocene. Science. 2014;**345**:401-406

[2] Samways MJ. Insect Conservation Biology. London: Chapman and Hall; 1994. 358p

[3] Mawdsley NA, Stork NE. Species extinctions in insects: Ecological and biogeographical considerations. In: Harrington R, Stork NE, editors. Insects in a Changing Environment. London: Academic Press; 1995. pp. 321-369

[4] Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, et al. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS One. October 18, 2017:1-5. DOI: 10.137/journal.pone.0185809

[5] Ripple WJ, Wolf C, Newsome TM, Galetti M, Alamgir M, Crist E, Mahmoud MI, Laurance WF, et al. World scientists' warning to humanity: A second notice. BioScience. 2017;**67**:1026-1028. DOI: 10.1093/biosci/bix125/4605229

[6] Ceballos G, Ehrlich PR, Barnosky AD, Garcia A, Pringle RM, Palmer TM. Accelerated modern human-induced species losses: Entering the sixth mass extinction. Science Advances. 2015. E1400253 June 2015:1-5

[7] Labandeira CC, Johnson KR, Wilf P. Impact of the terminal cretaceous event on plant-insect associations. Proceedings of the National Academy of Sciences USA. 2002;**99**:2061-2066

[8] Ponel P, Orgeas J, Samways MJ, Andrieu-Ponel V, de Beaulieu J-L, et al. 110 000 years of quaternary beetle diversity change. Biodiversity and Conservation. 2003;**12**:2077-2089

[9] Travis JMJ. Climate change and habitat destruction: A deadly anthropogenic cocktail. Proceedings of the Royal Society of London B. 2003;**270**:467-473

[10] Chan KM, Balvanera P, Benessaiah K, Chapman M, Dìaz S, et al. Why protect nature? Rethinking values and the environment. Proceedings of the National Academy of Sciences, USA. 2016;**113**:1462-1465

[11] Knight TM, McCoy MW, Chase JM, McCoy KA, Holt RD. Trophic cascades across ecosystems. Nature. 2005;**437**:880-883

[12] Williams BL. Conservation genetics, extinction, and taxonomic status: A case history of the regal fritillary. Conservation Biology. 2002;**16**:148-157

[13] Casacci LP, Barbero F, Balletto E. The "Evolutionarily Significant Unit" concept and its applicability in biological conservation. The Italian Journal of Zoology. 2014;**81**:182-193

[14] Barnett LK, Warren MS. Species Action Plan: Large Copper *Lycaena dispar*. Colchester, Essex, UK: Butterfly Conservation; 1995. p. 42

[15] Lindman L, Remm J, Saksing K, Sober V, Õunap E, Tammaru T. *Lycaena dispar* on its northern distribution limit: An expansive generalist. Insect Conservation and Diversity. 2015;**8**:3-16

[16] Ware JL, Simaika JP, Samways MJ. Biogeography and divergence time estimates of the relic South African Cape dragonfly genus Syncordulia: Global significance and implications for conservation. Zootaxa. 2009;**2216**:22-36

[17] Prosser SW, Dewaard JR, Miller SE, Hebert PDN. DNA barcodes from century-old type specimens using next-generation sequencing. Molecular Ecology Resources. 2016;**16**:487-497

[18] Conserva 21. Natural England's Conservation Strategy for the 21st Century. 2016. 11p. www.gov.uk/natural-england

[19] Cardoso P, Erwin TL, Borges PAV, New TR. The seven impediments in invertebrate conservation and how to overcome them. Biological Conservation. 2011;**144**:2647-2655

[20] Foottit RG, Adler PH, editors. Insect Biodiversity: Science and Society. 2nd ed. Oxford, UK: Wiley-Blackwell

[21] Gerlach J, Hoffman BS, Hochkirch A, Jepsen S, Seddon M, et al. Terrestrial invertebrate life. In: Collen B, Böhm M, Kemp R, JEM B, editors. Spineless: Status and Trends of the World's Invertebrates. London, UK: Zoological Society of London; 2012. pp. 46-57

[22] Darwall W, Seddon M, Clausnitzer V, Cumberlidge N. Freshwater invertebrate life. In: Collen B, Böhm M, Kemp R, JEM B, editors. Spineless: Status and Trends of the World's Invertebrates. London, UK: Zoological Society of London; 2012. pp. 46-57

[23] Synthesis Team Co-chairs: Duraiappah AK, Naeem S. Millennium Ecosystem Assessment Ecosystems and Human Well-Being: Biodiversity Synthesis. Washington DC, USA: World Resources Institute; 2005. 25p

[24] Losey JE, Vaughan M. The economic value of ecological services provided by insects. BioScience. 2006;**56**:311-323

[25] Kleijn D, Winfree R, Bartomeus I, Carvalheiro LS, Henry M, et al. Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. Nature Communications. 2015;**6**:7414

[26] van Huis A, Van Itterbeeck J, Klunder H, Mertens E, Halloran A, et al. Edible Insects: Future Prospects for Food and Feed Security. Food and Agriculture Organization of the United Nations: Rome, Italy; 2013. 187p

[27] Mmari M. Can feeding young children a porridge made from insects improve their health status? Ruforum. Newsletter. 2017;**1**:9-12

[28] Chung J, Aguirre-Bielschowsky J. Ento: Introducing edible insects into the Western diet. Antenna. 2014;**38**(1):10-15

[29] Clayton S, Myers G. Conservation Psychology. Understanding and Promoting Human Care for Nature. Wiley-Blackwell: Oxford, UK; 2009. 253p

[30] Simaika JP, Samways MJ. Insect conservation psychology. Journal of Insect Conservation. 2018 (in press)

[31] Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin WE. Global pollinator declines: Trends, impacts and drivers. Trends in Ecology & Evolution. 2010;**25**:345-353

[32] Carson R. Silent Spring. Greenwich, Connecticut, Boston, USA: Fawcett; 1962. 378p

[33] Klein S, Cabirol A, Devaud J-M, Barron AB, Lihoreau M. Why bees are so vulnerable to environmental stressors. Trends in Ecology & Evolution. 2017;**32**:268-278

[34] Simaika JP, Samways MJ. Biophilia as a universal ethic for conserving biodiversity. Conservation Biology. 2016;**24**:903-906

[35] Balmford A, Green JMH, Anderson M, Beresford J, Huang C, et al. Walk on the wild side: Estimating the global magnitude of visits to protected areas. PLoS Biology. 2015;**13**:1-6. DOI: 10.1371/journal.pbio.1002074

[36] McCarthy DP, Donald PF, Scharlemann JP, Buchanan GM, Balmford A, et al. Financial costs of meeting global biodiversity conservation targets: Current spending and unmet needs. Science. 2012;**338**:946-949

[37] Roy DB, Ploquin EF, Randle Z, Risely K, Botham MS, et al. Comparison of trends in butterfly populations between monitoring schemes. Journal of Insect Conservation. 2015;**19**:313-324

[38] Lewandowski EJ, Oberhauser KS. Butterfly citizen scientists in the United States increase their engagement in conservation. Biological Conservation. 2017;**208**:106-112

[39] Zapponi L, Cini A, Bardiani M, Hardersen S, Maura M, et al. Citizen science data as an efficient tool for mapping protected saproxylic beetles. Biological Conservation. 2017;**208**:139-145

[40] Domroese MC, Johnson EA. Why watch bees? Motivations of citizen science volunteers in the Great Pollinator Project. Biological Conservation. 2017;**208**:40-47

[41] New TR. Insects, Fire and Conservation. Springer, New York, USA: Springer; 2014. 208p

[42] Tscharntke T, Tylianakis JM, Rand TA, Didham RK, Fahrig L, et al. Landscape moderation of biodiversity patterns and processes—Eight hypotheses. Biological Reviews. 2012;**87**:661-685

[43] Perfecto I, Vandermeer J. Biodiversity conservation in tropical agroecosystems: A new conservation paradigm. Annals of the New York Academy of Sciences. 2008;**1134**:173-200

[44] Samways MJ, Pryke JS. Large-scale ecological networks do work in an ecologically complex biodiversity hotspot. Ambio. 2016;**45**:161-172

[45] Pryke JS, Samways MJ. Ecological networks act as extensions of protected areas for arthropod biodiversity conservation. Journal of Applied Ecology. 2012;**49**:591-600

[46] Tscharntke T, Klein M, Kruess A, Steffan-Dewenter I, Thies C. Landscape perspectives on agricultural intensification and biodiversity—Ecosystem service management. Ecology Letters. 2005;**8**:857-874

[47] Carvalheiro LG, Kunin WE, Keil P, Aguirre-Gutiérrez J, Ellis WN, et al. Species richness declines and biotic homogenisation have slowed down for NW-European pollinators and plants. Ecology Letters. 2013;**16**:870-878

[48] Donald PF, Evans AD. Habitat connectivity and matrix restoration: The wider implications of agri-environment schemes. Journal of Applied Ecology. 2006;**43**:209-218

[49] Schneider MK, Lüscher G, Jeanneret P, Arndorfer M, Ammari Y, et al. Gains to species diversity in organically farmed fields are not propagated at the farm level. Nature Communications. 2014;**5**:4151

[50] New TR. Insect Conservation and Urban Environments. New York, USA: Springer; 2015. 244 p

[51] Samways MJ. Rescuing the extinction of experience. Biodiversity and Conservation. 2007;**16**:1995-1997

[52] Harari YN. Homo Deus: A Brief History of Tomorrow. Penguin Random House: London, UK; 2017. 513p