Insect decline reading after finishing essay

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| (Vanbergen and Initiative, 2013) | 4/5/22 | **Threats to an ecosystem service: pressures on pollinators**  **Abstract**  Here, we argue that multiple anthropogenic pressures – including land-use intensification, climate change, and the spread of alien species and diseases – are primarily responsible for insect-pollinator declines. We show that a complex interplay between pressures (eg lack of food sources, diseases, and pesticides) and biological processes (eg species dispersal and interactions) at a range of scales (from genes to ecosystems) underpins the general decline in insect-pollinator populations.  **Intro**  Globally, insects supply pollination services, valued at US$215 billion in 2005, to about 75% of crop species and enable reproduction in up to 94% of wild flowering plants.  While these different threats to pollinators have long been recognized (eg Kearns et al. 1998), most research has focused on their individual impacts and has overlooked the complex nature of the problem.  Here, we consider managed (mainly honey bees [Apis spp] but also some captive-reared bumblebee and solitary bee species) and wild (bumblebees, solitary bees, flies, butterflies, etc) insects with the potential to pollinate crops or wild plants.  **Implications of pollinator losses**  Pollinators provide a crucial ecosystem service by improving or stabilizing yields of approximately 75% of crop-plant species globally (Klein et al. 2007).  In the face of multiple threats to pollinators, any reliance on a single species for pollination services is a risky agricultural strategy.  If demand for insect pollinated crops continues to rise while pollinator numbers persistently fall (see Panel 1), then crop shortages will likely ensue in the absence of compensatory technical or economic responses.  Human health impacts will be magnified in developing countries, where insect-pollinated crops (eg beans) supply crucial subsistence calories and nutrients.  Pollinator declines could also have serious consequences for natural ecosystems. Estimates of flowering plant dependence on animal pollination vary between 78% and 94% in temperate and tropical ecosystems, respectively (Ollerton et al. 2011).  Such ecological changes could further affect human health, given that tropical plants are the source of many commercial nutritional supplements and could possess undiscovered medicinal properties as well (Eilers et al. 2011).  **Land-use intensification**  Urbanization and increasing agricultural intensification have destroyed and fragmented many natural habitats (Figure 1a) that pollinators rely on for forage and nesting resources.  Although mass flowering crops (eg canola) may offer alternative pollinator food in intensively managed landscapes (Westphal et al. 2003), they may compete with wild plants for pollinators and could alter pollinator communities by favouring those species able to exploit such flowering crops more effectively (Pleasants 1980). Furthermore, these types of crops often supply a short, synchronous pulse of floral resources that do not provide adequate nutrition for pollinators, especially those species with longer activity periods (Pleasants 1980).  Landscape-scale surveys of wild bees and butterflies show that species richness tends to be lower where pesticide loads and cumulative exposure risk are high (Brittain et al. 2010). Used widely in the developed world, systemic pesticides (eg neonicotinoids) spread throughout plant tissues and can accumulate in plant nectar and pollen, thereby producing sublethal negative effects on pollinator performance and behaviour (Cresswell 2011; Gill et al. 2012). Sublethal neonicotinoid exposure can impair brain function (Palmer et al. 2013) and the learned ability of foraging workers to relocate the hive in honey bees (Henry et al. 2012), and reduce the foraging performance, growth rate (Gill et al. 2012), and queen production of bumblebee (Bombus terrestris) colonies (Whitehorn et al. 2012).  **Climate change**  Plant and pollinator ranges are shifting, causing changes in pollinator populations that inhabit the edges of their species’ climatic range, so that they become more susceptible to population declines and even extinction as a result of climate change.  Differential migration rates of co-occurring plants and insects as a result of changing climatic conditions (Schweiger et al. 2008) may lead to a spatial dislocation of processes like pollination.  As well as affecting distributions, climate change may alter the synchrony between plant flowering and pollinator flight periods.  **Alien species**  Non-native plant species may co-opt pollinators and come to dominate plant–pollinator interactions by providing abundant foods for those pollinators that are pre-adapted to exploit them.  Alien pollinators – introduced accidentally or for agricultural purposes – can disrupt native pollinator communities by outcompeting indigenous insects for resources or by spreading pests and disease.  **Pests and pathogens**  Mortality due to pests and pathogens (Figure 1d) dominates explanations of honey bee decline in the developed world. The Varroa destructor mite is the primary vector of many viruses (Picornavirales) implicated in honey bee colony losses.  **Interacting pressures on pollinators**  Land-use intensification (and its concomitant impacts) and disease have long driven pollinator losses. Globalization and climate change may extend these impacts to developing regions, increasing the translocation of plants, pollinators, pests, and pathogens worldwide.  Compensatory species migration as a result of climate change might be inhibited by habitat loss and fragmentation.  Pollinators require an optimum nutrient balance to support their growth and reproduction but land-use change is preventing this and parasite and pathogen infections increase metabolic demands for specific nutrients; for instance, worker honey bees infected with the gut parasite Nosema ceranae increase their daily carbohydrate intake.  Recent laboratory studies have shown increased worker honey bee mortality and energetic stress due to the additive and synergistic interactions between N ceranae infection and sublethal doses of a neonicotinoid (Alaux et al. 2010a; Vidau et al. 2011) or phenylpyrazole pesticide (Vidau et al. 2011). | Threats to pollinators are well-described by Vanbergen and Initiative (2013), who highlight complex interactions between multiple drivers.  Loss of pollinators is likely to have serious ecological and economic consequences. Crop yields will suffer from lack of pollination, along with wild plants dependent on insect pollination, which could see the loss of undiscovered drugs (Vanbergen and Initiative, 2013).  Agricultural expansion and intensification leads to large areas of monoculture, which although can provide a resource for pollinators, the crops are often characterised by short periods of flowering, which is inadequate for pollinators with longer flight seasons (Vanbergen and Initiative, 2013).  Climate change is likely to lead to differential rates of migration by plants and insects leading to a mismatch between species which rely on one another (Vanbergen and Initiative, 2013).  Alien species outcompete native insect for resources and can additionally spread pests and diseases. Honey bees particularly suffer from pest and diseases (Vanbergen and Initiative, 2013). |
| (Miličić *et al.*, 2021) | 5/5/22 | **Insect threats and conservation through the lens of global experts**  **Abstract**  Expert opinion, which is often widely available, proves to be a valuable tool where hard data are limited.  Our aim is to use global expert opinion to provide insights on the root causes of potential insect declines worldwide, as well as on effective conservation strategies that could mitigate insect biodiversity loss.  The most relevant threats identified through the survey were agriculture and climate change, followed by pollution, while land management and land protection were recognized as the most significant conservation measures.  There were differences across regions and insect groups, reflecting the variability within the most diverse class of eukaryotic organisms on our planet.  **Intro**  Most insects are non-charismatic at best and perceived as pests at worst.  The most comprehensive study to date on insect declines is the one by van Klink et al. (2020). In this paper, the authors analysed data from a total of 149 studies encompassing 1240 different sites in order to establish abundance trends in populations of terrestrial and freshwater insects. This effort nonetheless suffered from geographic bias with 74% of studies focusing on the Holarctic region. Additionally, it also lacks an explicit summary of which taxa each of its datasets covered, instead exploring further details on the realms and stratums examined in each set. Finally, the mix of data suffers from several problems of interpretation (Desquilbet et al., 2020).  Turning to expert knowledge to generate comprehensive data gives us the opportunity to access and explore valuable nonconventional data.  **Results**  Expertise on the Western Palearctic (Figure 1) and on the orders Coleoptera, Lepidoptera, and Diptera were dominant.  In most cases, analyses per insect order revealed that the trends followed the global pattern, with agriculture, climate change, and pollution being identified as the most important threats for most orders.  In Hymenoptera, Hemiptera, and Diptera, education was identified among the most relevant conservation measures, next to land protection and land management.  Respondents of the query considered that the most relevant services provided by insects are within provisioning services, namely monitoring of habitat quality and bio-control (Figure 9). Among regulating services, pollination was depicted as the most significant, while nutrient cycling through saprophagy and coprophagy were the most relevant supporting services.  Pest damage to agriculture and acting as invasive species were selected as main disservices of insects.  **Discussion**  Although we are aware of the fact that expert opinion is prone to subjectivity, it has already proven to be highly beneficial for conservation science.  For global insect conservation it offers the best available scientific knowledge and fresh perspectives on regions and taxa that have largely remained unexplored.  A dominant contribution of a particular insect order to all these positive trends was not observed. This might be interpreted, albeit cautiously, as good news, indicating that there are taxa from different orders managing to cope with the existing pressures causing insect declines.  We hypothesize that the Afrotropics, Indomalayan, and Australasian regions (i.e., certain areas in those regions), which showed most stable and positive trends for different population metrics, are less affected by habitat loss than the others, providing relatively large areas of natural habitats, thus managing to sustain large and stable populations of different insect groups.  Nevertheless, it is noteworthy that in almost one third of the answers respondents selected unknown trends, which indicates that, even with the recent rise in the number of papers tackling insect declines, the most diverse class of animal organisms on the planet is still severely understudied.  Incorporating insects into protected area monitoring activities is possible only with well-documented species inventories (McGeoch et al., 2011), which brings us back to the recognized gaps in taxonomical, biological, and ecological knowledge of insects and the need to build unbiased monitoring programs at a global scale.   * local vs global threat – e.g. climate change vs volcano? | An alternative study approach is to collect expert knowledge. Though prone to subjectivity, this is especially useful when data are deficient and can provide fresh perspectives. However, even this study reported a high proportion of responses as unknown trend, highlighting how understudied this group are (Miličić et al., 2021).  The most important drivers of insect trends according to experts in (Miličić et al., 2021)’s study were agriculture and climate change. The main disadvantages of insects were identified as pest damage to crops and their impact as invasive species.  Paper made me think about local vs global drivers – climate change affects everywhere (not necessarily to the same extent) but volcanoes will be very localised. |
| (Eggleton, 2020) | 5/5/22 | **The State of the World’s Insects**  **Abstract**  Some decline has occurred, it is clear, due to agricultural intensification, urbanization, overuse of pesticides, and global climate change. A decline would seriously affect the ecosystem services that insects provide. However, there is too little data to warrant the belief that all insects are declining everywhere.  **Intro**  This is probably best shown by the “windshield (or “windscreen”) phenomenon,” the sense that the number of insects crashing into windscreens has declined steeply over the past few years or decades.  Insects appeared first in the Ordovician, approximately 480 million years ago, at approximately the same time as the first land plants evolved.  Insects were the first animals to evolve flight and have dispersed and diversified across most continents and into most niches from plant chewers to mammal parasites.  Given that they account for such a large proportion of global diversity, it is no surprise that humanity is concerned about their possible loss.  There are more than a million described insect species, and the present estimate is that the total number of living species of insects is 5.5 million (16).  Highest species richness of insects being in the tropics, especially in tropical rain forests, where they are often described as hyperdiverse (18).  If there are maybe 3–4 million species of insects, then the ants and termites make up approximately 1% of insect species but more than 50% of the biomass. The kings of the jungle are not the lion or the tiger, but the scurrying and tunneling hordes of social insects.  **Insects and humans**  Many ecosystem disservices that insects have always provided, particularly to agricultural crops (32), timber (33, 34), and stored products (34). They are vectors of diseases (35), most famously as carriers of malaria; threats to hygiene, e.g., flies and cockroaches infecting food with bacteria (36); and general nuisances, particularly swarming flies (37).  Provided food (43), pollination (e.g., honey bees) (44), and pest control (45) or were considered attractive or symbolic (46). However, in the past few decades, it has been realized that insects provide many useful ecosystem and cultural services: Many insects pollinate crops (47). These include bees, both social and solitary, moths and butterflies, wasps, and flies. Bees are thought to be the most important.  Hymenopteran and coleopteran predators and parasitoids can help in pest control (53), by feeding on pest species, such as caterpillars or Hemiptera. Soil insects (especially dung beetles and termites) assist soil fertility, by their transformation of soil (54), by soil bioturbation (55), by the way that they aid plant decomposition (56) and by assisting nutrient cycling (57).  **The historical record**  It seems that this background historical level of insect reductions was mostly not commented on (or just not noticed by scientists) in the literature before approximately 1980. This is partially due to a very different attitude to the natural world before then (68) and due to a lack of understanding of the many beneficial roles of insects.  **Catastrophic decline?**  Papers with 'insect decline' in – 16 in 2000s, 163 in 2010s.  Is the decline really speeding up, or is it moving at the same rate but we are just finally becoming aware of it?  There is no doubt that human acts have caused a decline in insects; what is at question is whether there has been a sudden change in the rate of decline—whether we have reached a tipping point, the limits of resilience, where the world has lost many species and many ecological services permanently.  Criticism of Lister and Garcia, 2018 - However, the study has been heavily criticized for using only temperature as a possible cause of this decline and ignoring the effect of human disturbance and Hurricane Hugo. The critique also questioned the use of data. There was also concern that the data were not adjusted for differences in sampling effort, combining studies that are not strictly compatible, particularly within the temperature record. In the critique’s reanalysis they found no evidence for a decline with temperature or for a collapsing food web (84 - Willig MR, Woolbright L, Presley SJ, Schowalter TD, Waide RB, et al. 2019. Populations are not declining and food webs are not collapsing at the Luquillo Experimental Forest. PNAS 116:12143–44).  Criticism of Sanchez\_Bayo - except for the Lepidoptera, the taxonomic coverage was poor in the orders. In Hymenoptera, it was heavily biased toward pollinator taxa (bumble bees and honeybees) and in Coleoptera toward dung beetles. This is not in itself necessarily a shortcoming of the review, but simply identifies that groups that provide useful ecosystem services to humans have been studied more carefully. However, there have been complaints about this paper (e.g., 85), emphasizing the limited geographical range and flawed study design, particularly their search strategy of examining only drivers that were associated with studies where there was a decline.  **Causes**  There is little doubt that the declines in insects are human-caused. There are no other major environmental changes that are not anthropogenic.  **Caveats**  This not only caused a reduction in insect diversity, but many factors also lead to ecological homogenization, as the species that survive (due to greater resilience, wider thermal tolerances, human introductions, etc.) spread like weeds across the world.  There are methodological problems with many of the studies (70), but the overarching problem is the limited nature of all the studies, in both time and space.  Local extinctions are not global extinctions, and we should not be fooled into thinking that because a bad thing is happening here that it is happening everywhere. There may always be refugia from which species can recolonize areas, and apparently extinct species may well reappear. It is impossible to calculate extinction rates from the existing data, however. We still do not know how serious the problem really is for human well-being and the health of the planet generally.  The taxonomy of immature forms is much less developed than that of adults, with many species having undescribed larvae.  The truth is we cannot really say, and the data are contradictory, but it is reasonable for the global community to be alarmed.  Our lack of data from the tropics is unhelpful, particularly from tropical rain forests. Conversion of tropical forest to agricultural land reduces insect diversity and biomass.  This could include declines in pollination, soil fertility, and nutrient cycling, as well as an increase in the number of crop pests. The consequences of a decline in diversity, in itself, are uncertain and controversial, but high diversity is increasingly seen as a property adding to habitat resilience (161).  **Future issues**  Research is needed to help the insect taxonomic bottleneck, by finding ways of describing species at a faster rate, especially by incorporating DNA techniques into insect taxonomy using DNA barcoding and metabarcoding.  Improved land management is needed, with less tidying up of agricultural edges, verges, and reduction of so-called “weeds.” | Of the 5.5 million insects estimated to exist, we have only described just over 1 million of these (from (Stork, 2018)). This combined with patchy data, especially in the tropics, makes it difficult to properly assess the current state of insects. It appears there is enough evidence for concern though it is unlikely that insects are declining everywhere. We cannot extrapolate local extinctions to global extinctions. Furthermore, with a ten-fold increase in the number of studies published which include ‘insect decline’ from 200 to 2010, it is really the case that insects are declining alarmingly now, or that we are only just becoming aware of it (Eggleton, 2020)?  The lack of focus on insects in the past may be due to over-focus on the disadvantages of insects including agricultural pests, disease vectors, and general nuisances. The outweighing positive services including pollination, pest control, and nutrient cycling have been widely overlooked until recently (Eggleton, 2020).  It is human-caused changes that are driving the observed declines (Eggleton, 2020). |
| (An *et al.*, 2015) | 6/5/22 | **Space–Time Analysis: Concepts, Quantitative Methods, and Future Directions**  **Abstract**  Space–time analysis seeks to understand when and where (and sometimes why) things occur.  Based on more than 700 articles (from 1949 to 2013) we obtained through a key word search on the Web of Knowledge and through the authors’ personal archives, this article provides a synthetic overview about the quantitative methodology for space–time analysis.   * **Rest of paper not that relevant to ecology** | **N/A** |
| (Titley *et al.*, 2017) | 6/5/22 | **Scientific research on animal biodiversity is systematically biased towards vertebrates and temperate regions**  **Abstract**  Compared to the proportions of described species, we identified a considerable taxonomic weighting towards vertebrates and an under-representation of invertebrates (particularly arachnids and insects) in the published literature. This discrepancy is more pronounced in highly cited papers, and in tropical regions, with only 43% of biodiversity research in the tropics including invertebrates.  Biodiversity research is also biased geographically: studies are more frequently carried out in developed countries with larger economies, and for a given level of species or threatened species, tropical countries were understudied relative to temperate countries.  **Intro**  Estimates for global species richness typically fall in the range of 3 million to 100 million species [5] although a working figure between 5 and 15 million is often suggested [6].  Contrary to this uncertainly, it is well established that diversity is not evenly distributed amongst taxa. Arthropods, and especially insects, account for most known eukaryote species: of the 1.2–2 million described species, approximately 925,000 are insects [7,8].  For example, only 70 modern insect extinctions have been documented, despite thousands being estimated to have occurred [13].  **Results**  Approximately half of the papers sampled studied vertebrates, and half studied invertebrates (Fig 2). However, this is far from the true proportions of described species, where over 95% of species are invertebrates.  Of the top 25% most cited papers in the sample, only 47% included invertebrates, compared with 57% of the entire sample.  In terms of the proportion of studies, the bias towards vertebrates was greater in tropical regions than temperate regions (Chi-square test, X2 = 30.65, N = 672, P<0.001) (Fig 4). In tropical countries, 43% of studies included invertebrates, compared to 63% in temperate countries.  The United States of America had the highest number of studies of any country in the sample, but the density of biodiversity research appears to be generally highest in Western Europe.  **Discussion**  Mammals, which make up around 0.4% of known animal species [20], were studied in approximately 12% of papers with biodiversity in the title. The equivalent numbers for birds are 0.7% and 13%. In contrast, insects make up at least 70% of animal species [20] yet were studied in less than a quarter (23%) of papers. Due to the high proportion of species remaining to be described, particularly among the invertebrates, this figure is likely to be conservative.  Therefore, we are likely to continue to undervalue these under-studied groups, especially in parts of the world where they are most threatened, and perhaps allocate less funding to their protection. | Insects continue to be undervalued by researchers. Of the papers analysed by (Titley et al., 2017), an even split was found between papers reporting on vertebrates in invertebrates. This is a substantial difference to the proportions of species in existence where 95% are invertebrates. This lack of representation in the literature could result in a lack of funding for these so-called ‘unimportant’ species. |
| (Stork, 2018) | 6/5/22 | **How Many Species of Insects and Other Terrestrial Arthropods Are There on Earth?**  **Abstract**  Taking the mean of most of these new estimates indicates that globally there are approximately 1.5 million, 5.5 million, and 7 million species of beetles, insects, and terrestrial arthropods, respectively.  Previous estimates of 30 million species or more based on the host specificity of insects to plants now seem extremely unlikely.  With 1 million insect species named, this suggests that 80% remain to be discovered.  **Intro**  In recent years, potential new support for hyper estimates of insect species has come from DNA studies that have shown previously unresolved species complexes may constitute numerous species. Such cryptic diversity has been called the biodiversity wildcard (6).  What we do know is that there has been disproportionate research effort into more charismatic groups such as birds and mammals, which has resulted in a much lower average number of research papers per known species of insects. | (Stork, 2018) approximate there to be 5.5 million insects in existence, though only 1 million have been described. |
| (Willig *et al.*, 2019) | 6/5/22 | Criticism of Lister and Garcia, 2018.  **Populations are not declining and food webs are not collapsing at the Luquillo Experimental Forest**  Lister and Garcia (1) report declines in abundances of understory arthropods and lizards between 1976 and 2012 and claim similar declines in populations of arthropods, frogs, and insectivorous birds based on data from the Luquillo Long-Term Ecological Research project (LUQ).  Their conclusion, that increasing temperature has led to a collapse of the food web, has attracted considerable attention from public media.  The authors fail to consider the effects of hurricanes and subsequent changes during secondary succession.  Abundance data are not adjusted to consider variation in sampling effort.  Moreover, the authors combine data files that are not compatible to create the temperature record for analyses.  Using Lister and Garcia’s (1) analytical approach for temporal trends, we found a significant decline in density of Lamponius from 1993 to 2011, but density was not statistically related to temperature during this period.  We found no evidence to support the conjecture that food webs are collapsing at LUQ as a result of warming. The narrow focus on temperature-related aspects of climate change as the causative agent does not address the multiple disturbances (e.g., hurricanes and droughts) that affect the forest (8). | (Willig et al., 2019) replicate some of the analysis performed by Lister and Garcia (2018), concluding completely contrasting results. They report no evidence that declines are occurring due to climate warming. This could be due to Lister and Garcia (2018) failing to account for effects such as droughts and hurricanes in addition to temperature related aspects of climate change. Further, abundance data was not adjusted according to sampling effort, which could lead to erroneous results. |
| (Lawton *et al.*, 1998) | 12/5/22 | **Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest.**  Despite concern about the effects of tropical forest disturbance and clearance on biodiversity1,2, data on impacts, particularly on invertebrates, remain scarce.  Here we report a taxonomically diverse inventory on the impacts of tropical forest modification at one locality. We examined a gradient from near-primary, through old-growth secondary and plantation forests to complete clearance, for eight animal groups (birds, butterflies, flying beetles, canopy beetles, canopy ants, leaf-litter ants, termites and soil nematodes) in the Mbalmayo Forest Reserve, south-central Cameroon.  Although species richness generally declined with increasing disturbance, no one group serves as a good indicator taxon9–12 for changes in the species richness of other groups.  Species replacement from site to site (turnover) along the gradient also differs between taxonomic groups.  The proportion of ‘morphospecies’ that cannot be assigned to named species and the number of ‘scientist-hours’ required to process samples both increase dramatically for smaller-bodied taxa.  Data from these eight groups indicate the huge scale of the biological effort required to provide inventories of tropical diversity, and to measure the impacts of tropical forest modification and clearance.  Richness in some groups was surprisingly insensitive to extreme habitat modification, and not all taxa had maximum species richness in near-primary (NP) or old-growth secondary (OS) sites.  We conclude that attempts to assess the impacts of tropical forest modification and clearance using changes in the species richness of one or a limited number of indicator taxa9–12 (including popular groups such as birds or butterflies) to predict changes in richness of other taxa may be highly misleading.  Maximum diversity in tropical forests will be conserved by maintaining a mosaic of habitats, including large tracts of primary and old-growth secondary forest. | We cannot generalise results from studies on species other than invertebrates to invertebrates due to Lawton et al. (1998)’s findings that no one animal group could be used as a reliable predictor for change in species richness across a gradient of increasing disturbance of other groups. |
| (Newbold *et al.*, 2018) | 12/5/22 | **Widespread winners and narrow-ranged losers: Land use homogenizes biodiversity in local assemblages worldwide.**  **Abstract**  Human use of the land (for agriculture and settlements) has a substantial negative effect on biodiversity globally. However, not all species are adversely affected by land use, and indeed, some benefit from the creation of novel habitat.  Geographically rare species may be more negatively affected by land use than widespread species, but data limitations have so far prevented global multi-clade assessments of land-use effects on narrow-ranged and widespread species.  Compared with natural habitat, assemblages in disturbed habitats have more widespread species on average, especially in urban areas and the tropics. All else being equal, this result means that human land use is homogenizing assemblage composition across space.  The shift to more widespread species may also affect ecosystem functioning by reducing both the contribution of rare species and the diversity of species’ responses to environmental changes among local assemblages.  **Intro**  Land use is currently among the predominant pressures on biodiversity globally [4], with substantial net losses of species in land-use types dominated by human activities [5].  Crucially, small range size is a key determinant of species’ extinction risk [8–10], and therefore a disproportionate impact of human land use on small-ranged species would have important consequences for biodiversity conservation.  Furthermore, rare species (including geographically restricted species) tend to have unique combinations of functional traits and are therefore likely to make an important contribution to ecosystem functioning [11], meaning that a disproportionate loss of small-ranged species would have implications beyond their immediate conservation interest.  Effects of land conversion on beta diversity are scale dependent [20]. For example, partial conversion of a natural landscape can increase beta diversity at the landscape scale while decreasing it globally.  Measures based on the average range size of species within a community, such as RCAR and RAR used here, are always expected to increase whenever homogenization occurs.  We combined a dataset of 1.1 million records from 445 surveys (Fig 1 and S1 Fig) that compared the abundance of 19,334 species of terrestrial plants (7,111 species), invertebrates (7,048 species), and vertebrates (5,175 species) among different land uses [21], with occupancy- or extent-based estimates of all species’ range sizes using records from the Global Biodiversity Information Facility.  **Results**  Overall, land use had a strong effect on both RCAR and RAR. Assemblages in all human-dominated land uses (plantation forests, croplands, pasture, and urban environments) have higher average RCAR than those in natural vegetation types.  Within land-use categories, RCAR increased significantly with increasing human land-use intensity.  Specifically, a longer history of human domination of landscapes was associated with a strong increase in RCAR in urban environments but with decreased RCAR in cropland, plantation forest, pasture, and mature secondary vegetation.  RCAR increased much more strongly in human-dominated land uses in the tropics than in the temperate realm.  Homogenization implies that narrow-ranged species tend to decline in occurrence or abundance, that widespread species tend to increase, or both.  **Discussion**  Our results imply that human land use is causing a similar homogenization of community composition for many different taxonomic groups globally.  In general, species with narrow ranges are the most likely to be threatened with extinction because the drivers of threat are more likely to affect the entire range of these species [8]. More specifically, narrow ranges will tend to reflect more specific climatic requirements and thus greater sensitivity to climate change. Given this, our results suggest that the same species are likely to be sensitive to both land use and climate change  Increases in RCAR and RAR were strongest in the tropical realm. There are three possible —likely interconnected—reasons for this difference. First, native tropical species tend to have smaller average ranges than temperate species [32], increasing the contrast with wide-ranging newcomers.  Responses of community-average range sizes varied strongly among taxonomic groups, with the largest increases in RCAR and RAR in human-modified land uses for reptiles, plants, and mammals, and the weakest for invertebrates. The reasons for these taxonomic differences are not clear, and we caution that they may to some extent reflect variation in the quality of range-size estimates. Varying quality of range-size estimates is especially likely to explain the weak responses for invertebrate species, given that invertebrate ranges are likely to be the most incompletely defined, and narrow-ranged invertebrates have been shown to be less likely to be captured in incomplete surveys.  The greatest challenge here was in the estimation of range sizes. For most species, highly accurate range-size estimates will not be available for the foreseeable future.  **Methods**  We extracted data from the Projecting Responses of Ecological Diversity In Changing Terrestrial Systems (PREDICTS) database. | Newbold et al. (2018) report that land-use change is causing a shift to more widespread species, and thus resulting in a homogenisation. This was true for plants and vertebrates, as well as invertebrates using the PREDICTS database records. |
| (Hillebrand *et al.*, 2018) | 13/5/22 | **Biodiversity change is uncoupled from species richness trends: Consequences for conservation and monitoring**  **Abstract**  Here, we summarise several limitations of species richness as a metric of biodiversity change and show that the expectation of directional species richness trends under changing conditions is invalid. Instead, we illustrate how a set of species turn-over indices provide more information content regarding temporal trends in biodiversity, as they reflect how dominance and identity shift in communities over time.  In all datasets, nearly complete species turnover occurred, but this was disconnected from any species richness trends. Instead, turnover was strongly influenced by changes in species presence (identities) and dominance (abundances).  In fact, reductions in environmental quality can lead to transient increases in species richness if immigration or extinction has different temporal dynamics. Thus, biodiversity monitoring programmes need to go beyond analyses of trends in richness in favour of more meaningful assessments of biodiversity change.  **Intro**  These changes in biodiversity have led to what is often called a “biodiversity crisis,” with warnings that current rates of extinctions are exceptionally high (Mace et al., 2005; Pimm et al., 2014), indicating a global mass extinction phenomenon (Barnosky et al., 2011, 2012).  There is little agreement on how to monitor and quantify biodiversity change.  Although there is little doubt that biodiversity is declining at the global scale, assessing biodiversity change at scales smaller than the globe is not as straightforward as often assumed.  Indeed, a series of recent publications synthesising time series on biodiversity change have suggested that local-scale biodiversity—typically measured as species richness—is not systematically declining (Dornelas, Gotelli, et al., 2014; Elahi et al., 2015; Vellend et al., 2013). The results of these meta-analyses have been criticised for a variety of technical issues (Gonzalez et al., 2016; see reply by Vellend et al., 2017), and other meta-analyses have shown decreasing trends of local species richness in the face of intensive land-use (Newbold et al., 2015).   * These MAs were not specifically about insects, or about insects at all   On the surface, the result that the most commonly used metric to detect biodiversity trends—species richness—does not appear to be systematically declining locally might be taken to suggest that the “biodiversity crisis” has been overblown, or at least is not as straight-forward as often implied (Thomas, 2013; Vellend, 2017).  On the contrary, however, we posit here that the paucity of empirical evidence for biodiversity change stems from the widespread use of inadequate tools to capture and quantify the ongoing change caused by humans, rather than the non-existence of exceptional biodiversity change.  Biodiversity thus not only includes richness, i.e., the number of species, but also aspects of identity, dominance and rarity. Consequently, biodiversity change comprises more than a reduction in species richness; for example, the decline of long-lived foundation species and their replacement by smaller, weedy ones (Lotze et al., 2006) may not change total species number, but changes the identity of species and consequently the functional traits (structure, longevity) associated to these.  **Trends in richness do not capture biodiversity change**  Biodiversity is a multifaceted construct, comprising genetic, taxonomic, phylogenetic and ecological components. Unfortunately, a single facet of biodiversity, species richness, has become the most dominant measure of biodiversity and its change (Appendix S1), as it is easily observed and recorded, making it a relatively affordable means to monitor change in natural ecosystems.  First, species richness is a highly scale-dependent measure owing to the ubiquitous species-area relationship. Any comparisons of species richness from different sites or time periods will depend on the scale at which observations are made.  Simply comparing changes in species richness, or the lack thereof, tells us little about which of the components that underlie species richness estimates actually changed (i.e., whether the numbers of rare species, the numbers of individuals or the entire SAD [species abundance distribution] changes).  The lack of a temporal trend in species richness (e.g. Dornelas, Gotelli, et al., 2014; Elahi et al., 2015; Vellend et al., 2013) does not mean that species composition remains unchanged, but only that immigration and extinction events are equally frequent.  The rates of change in species composition are often decoupled from changes in richness for a number of reasons. First, immigrations and extinctions can be equally high, leading to strong—even complete— turnover with little concomitant change in species richness.  Colonising species increase species richness as soon as the first individual is recorded, while species loss is often slower because it involves population dynamics leading to local extinction, a phenomenon described as extinction debt. Alternatively, there can also be a lag in immigration in isolated habitats or when colonising taxa have low dispersal ability (Isbell, Tilman, Polasky, Binder, & Hawthorne, 2013; Seabloom et al., 2006), known as immigration credit (Jackson & Sax, 2010).  We introduce the general term “species exchange ratio” (SER) here to clarify its purpose in the context of monitoring as measuring the proportional exchange of species between an earlier and later sample in a time series.  **Results**  None of the three monitoring datasets revealed strong temporal changes in annual species richness (Figure 2a–c). From a total of 187 sites across all datasets, the majority (113 sites) showed no significant trend in either richness or log richness.  The number of extinctions and immigrations between years did not vary substantially with time (Figure 2g–i, red and blue bands) either.  An almost complete exchange of the species inventory could be observed without a detectable change in richness in all three datasets.  **Discussion**  Major aspects of biodiversity change are not (and cannot be) reflected by changes in species richness.  The net change in number of species can be zero, but a valid conservation target can be to halt such a shift in species identity.  Although species turnover is a much more sensitive measure of biodiversity change (Dornelas, Gotelli, et al., 2014), presence-absence turnover indices alone are insufficient, as they—like richness itself— depend on species pool size and detection probability of rare species. Instead, we propose that combining a presence-based and a dominance-based measure of turnover (SERr and SERa) allows conclusions on the magnitude of co-occurring shifts in species identity and relative abundance from time series data.  Explicitly addressing the extent of extinctions and immigrations via SERr and dominance shifts via SERa.  Therefore, biodiversity assessments need a long memory to disentangle long-term from short-term changes and to reveal the full extent of biodiversity change. | Hillebrand et al. (2018) highlight the important differences between the use of different biodiversity metrics and why we should proceed with caution when reporting on trends using just one metric. Species richness alone cannot reflect changes in community composition, thus masking changes in species identity and functional traits. It could be therefore be concluded that the population is stable, when in fact there has been complete species turnover. |
| (Engelhardt *et al.*, 2022) | 13/5/22 | **Consistent signals of a warming climate in occupancy changes of three insect taxa over 40 years in central Europe**  **Abstract**  Recent climate and land-use changes are having substantial impacts on biodiversity, including population declines, range shifts, and changes in community composition. However, few studies have compared these impacts among multiple taxa, particularly because of a lack of standardized time series data over long periods.  Here, we compare climate and land-use driven occupancy changes in butterflies, grasshoppers, and dragonflies using an extensive data set of highly heterogeneous observation data collected in the central European region of Bavaria (Germany) over a 40-year period.  Using occupancy models, we find occupancies (the proportion of sites occupied by a species in each year) of 37% of species have decreased, 30% have increased and 33% showed no significant trend. Butterflies and grasshoppers show strongest declines with 41% of species each. By contrast, 52% of dragonfly species increased.  Temperature preference and habitat specificity appear as significant drivers of species trends.  We show that cold-adapted species across all taxa have declined, whereas warm-adapted species have increased.  In butterflies, habitat specialists have decreased, while generalists increased or remained stable. The trends of habitat generalists and specialists both in grasshoppers and semi-aquatic dragonflies, however did not differ.  **Intro**  There is still a lack of understanding about the generality of insect declines across taxa.  New analytical methods, such as hierarchical Bayesian occupancy detection models, allow for reliable estimates of species occurrences from heterogeneous data sources (Outhwaite et al., 2020).  Hence, assessments of the effects of attributes on the trends of species within a community have become a popular way of understanding the effects of global change. Some species attributes, such as a broad habitat breadth or geographic range size, may lower the vulnerability to anthropogenic changes.  **Methods**  We focussed on the last 40 years from 1980 to 2019 as the number of samples in this time frame is reasonably high.  We constructed occupancy models for 300 species.  The occurrence probability (ψ) is a function of year (t) and site (i) variation, the latter decomposed into ecoregion (97 factor levels) and site (5 km grid). The best estimate of occupancy for each species and site per year is given as zi,t , which can be described by a Bernoulli distribution.  We based our occupancy models on Outhwaite et al. (2018), using a random walk prior distribution to share information across years for the year effect on the occupancy. For the other parameters, we used vague prior distributions. We fit the occupancy models using JAGS.  We assessed species linear trends for the study period between 1980 and 2019, using Bayesian generalized linear models from the R-package brms (Bürkner, 2017), which fits Bayesian models in stan (Stan Development Team, 2022b) via rstan (Stan Development Team, 2022a) for each species.  To analyse the potential effects of insect attributes on the change of distribution over the years, we applied Bayesian generalized linear mixed-effect models, using brms (Bürkner, 2017) for each taxon separately. We used the best estimate of annual occupancy (that is, the mean of the posterior distribution) of each modelled species per taxon as response variable in the models. Explanatory variables were year, selected attribute variables and their interaction with year.  **Results**  We found widespread variation in species' occupancy trends, estimated as annual change in the proportion of occupied sites, within as well as between insect taxa.  The attribute affecting species' occupancy trends with the highest significance across taxa was temperature preference—the higher the preferred temperature, the greater the increase in the proportion of occupied sites over the last 40 years.  Neither precipitation preference nor European range size had a significant effect on species trends over time.  Habitat specialization had a negative effect on distribution change for butterflies, but not for the other two taxa (Figure 3). At the beginning of our study period, butterflies specialized to certain habitats had slightly larger distributions than habitat generalists (Figure 4d). Over time, specialist butterfly species decreased their occupancy, while the occupancy of habitat generalists increased.  Habitat preferences (open vs forest, lentic vs lotic) had no significant effect on species distribution trends.  **Discussion**  Our analyses revealed climate change as a key driver of insect distributional changes.  Our results show that responses to increased temperatures are strongest for dragonflies. More than half of the dragonfly species have significantly increased their distributions since the 1980s, which is likely associated with their relatively high dispersal capacity (Bowler et al., 2021; Grewe et al., 2013) in combination with the improved quality of aquatic habitats (Dahl et al., 2016; Karle-Fendt & Stadelmann, 2013; Termaat et al., 2015).  Our study, however, reveals that some insect taxa are able to respond quicker than others.  Occupancies of butterflies that inhabit a small number of habitat types in the study region decreased, while butterfly generalists increased their occupancy. This effect of habitat specialization did not appear in the other two taxa. While 83% of our butterfly species are considered habitat specialists, only 61% of grasshopper and 60% of dragonflies are classified as such. The occurrence of specialized species often depends mostly on habitat quality, followed by habitat area (Löffler & Fartmann, 2017; Poniatowski et al., 2018; Thomas et al., 2011). Increased land-use intensity as well as abandonment leads to a decrease in habitat quality, especially for species of open habitats, and land-use change can lead to a dominance of certain habitats (Dou et al., 2021; Stoate et al., 2009). Therefore, the decrease of butterfly specialists could hint towards a threat associated with land-use, which might affect butterflies more strongly than the other taxa as a larger proportion of species is highly specialized.  Our study highlights the great potential of previously unused data sources to increase the understanding of distribution trends of insects over the past decades. Occupancy models facilitate the analysis of species trends for previous decades where no systematic monitoring data are available and the collected data are highly heterogeneous.  In this study, we focused on changes in distribution and not changes in abundance, which are different aspects to consider when assessing changes in species' status. Species abundance can decrease while at the same time range shifts can lead to an increase in species distribution.  This study focuses on three taxa that are rather well documented and amongst the more species-poor insect groups. To fully understand long-term trends in insect diversity and abundance we still need large-scale, standardized, multi-taxon monitoring programs.  Examining changes in potential drivers explicitly is an important aspect of future research into insect trends. | Engelhardt et al. (2022) use Bayesian occupancy models to study trends in butterflies, grasshoppers, and dragonflies in Germany from 1980 to 2019. Overall, 37%, 30%, and 33% of species have decreased, increased, and stayed stable, respectively.  Temperature preference and habitat specificity both impacted the trends observed, with the former being most significant. Species with higher temperature preferences increased the most in occupancy across all taxa. Butterfly habitat specialists decreased across the study period, but the same was not true for grasshoppers and dragonflies. This may be due to butterflies possessing a higher proportion of specialised taxa, the existence of which are associated with high quality habitats. These results indicate land-use as a potential driver which particularly affects the butterfly taxa (Engelhardt et al., 2022).  (Engelhardt et al., 2022)’s study highlight the importance of best utilising existing datasets, rather than having the expend additional resources on new data collection. |
| (Klein *et al.*, 2007) | 8/6/22 | **Importance of pollinators in changing landscapes for world crops**  **Abstract**  87 of the leading global food crops is dependent upon animal pollination, while 28 crops do not rely upon animal pollination.  Global production volumes give a contrasting perspective, since 60% of global production comes from crops that do not depend on animal pollination, 35% from crops that depend on pollinators, and 5% are unevaluated. | Over 75% of the crops examined by Klein et al. (2007) relied upon animal pollination. |
| (Gillespie *et al.*, 2022) | 27/6/22 | **Landscape-scale drivers of pollinator communities may depend on land-use configuration**  **Abstract**  Here, we use a network of 96 study landscapes in six topographically diverse regions of Britain, to test the combined importance of honeybee density, insecticide loadings, floral resource availability and habitat diversity to pollinator communities.  Positive association between abundance and floral resources depended on insecticide loadings and habitat diversity.  These results demonstrate that improving pollinator community composition and health is unlikely to be achieved with general resource enhancements only. Rather, local land-use context should be considered in fine-tuning pollinator management and conservation.  **Intro**  High densities of managed honeybees may be a stressor for wild bee populations under some conditions [7], due to competition for floral resources [14] or due to the increased risk of pathogen spill over [15].  We predicted that, in line with previous work, managed honeybee densities and insecticide application would have negative impacts on wild pollinator community composition across the country [7,36]. Conversely, we predict floral resources and habitat diversity to have positive impacts due to their importance in enhancing pollinator health at individual, population and community levels.  **Methods**  We therefore use more convenient diversity and abundance measures as indicators of community health, as it is reasonable to expect that landscapes with many populations able to optimally use resources to improve fitness, are likely to result in diverse and abundant communities.  Within each of the six regions, 16 study sites measuring 2 × 2 km were selected along four gradients: (i) honeybee densities, (ii) insecticide loadings, (iii) floral resource availability, (iv) habitat diversity values.  The 16 sites chosen for each region were thus considered to represent every combination of relatively high and low values for each of the four gradients.  For the confirmatory models, we fitted generalized linear mixed models (GLMM) to each response with the four drivers (honeybees, insecticides, habitat diversity and floral resource availability).  **Results**  In total, we collected 20 236 insect pollinators representing 294 species, with a greater number of individuals and species collected in 2012.  The four target drivers as main effects in our GLMMs did not significantly affect the abundance of total pollinators, or of bumblebees or hoverflies when considered separately (electronic supplementary material, table S8), but there was a positive association between managed honeybee density and solitary bee abundance.  We only found two significant interactions between the focal drivers.  First, the effect of floral resource availability on total pollinator abundance depended on insecticide loadings in the surrounding landscape, with the positive influence of floral resource availability most pronounced when loadings were absent, and the association apparently reversed at high loadings, although with high uncertainty.  Second, the association between floral resource availability and bumblebee abundance depended on habitat diversity, suggesting that floral resources were more beneficial to bumblebees in landscapes with diverse habitats.  **Discussion**  Nevertheless, in landscapes where insecticides were not applied, we found positive effects of other drivers such as floral resource availability, resource diversity and habitat proximity. Interestingly, floral resource availability and diversity appeared to have a negative association with pollinators in the presence of insecticides.  We interpret this as an increased exposure to insecticide in the presence of abundant and diverse food resources, such as in chemically treated mass-flowering crops [59], or because forage plants in adjacent uncultivated habitats can be sources of insecticide exposure for pollinators via drift or soil pathways.  These studies suggest that higher amounts of SNH (semi-natural habitat) in the landscape support pollinator communities by providing a refuge from intensive agricultural practices such as chemical application.  **Conclusion**  Our results are difficult to distil into simple, generalizable statements. We found rather few simple effects of the often cited key drivers of pollinator community composition and distribution across highly variable topographic areas.  This suggests that such variables do not generalize well across regions that are characterized by their land use, climate and management.  Thus, instead of simply relying on boosting pollinator resources to rectify otherwise unhealthy management practices, we recommend that pollinator conservation should be fine-tuned in relation to local land-use context. | Determining the effect of drivers on pollinators trends is unlikely to be straightforward. For example, Gillespie et al. (2022) found a positive effect of floral resource availability on total pollinator abundance when insecticides were absent. An uncertain opposite trend was found for high insecticide loadings. The effects were not simple, nor could they be generalised due to high geographic variation. |

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