Preliminary reading on insect declines

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| (Hallmann et al., 2017)  This one is an important read, one of the recent papers that has been a big element of the developing debate | 31/3/22 | **More than 75 percent decline over 27 years in total flying insect biomass in protected areas**  **Abstract**  Measure total insect biomass using Malaise traps, deployed over 27 years (1989-2016) in 63 nature protection areas in Germany.  Our analysis estimates a seasonal decline of 76%, and mid-summer decline of 82% in flying insect biomass.  Decline is apparent regardless of habitat type, while changes in weather, land use, and habitat characteristics cannot explain this overall decline.  **Intro**  Loss of insects is certain to have adverse effects on ecosystem functioning, as insects play a central role in a variety of processes, including pollination [1, 2], herbivory and detrivory [3, 4], nutrient cycling [4] and providing a food source for higher trophic levels such as birds, mammals and amphibians.  Climate change, habitat loss and fragmentation, and deterioration of habitat quality have been proposed as some of the prime suspects responsible for the decline [9–11, 13, 18–22].  However, the number of studies on insect trends with sufficient replication and spatial coverage are limited [10, 23–25] and restricted to certain well-studied taxa.  To what extent total insect biomass has declined, and the relative contribution of each proposed factor to the decline, remain unresolved yet highly relevant questions for ecosystem ecology and conservation.  **Methods**  Most locations (59%, n = 37) were sampled in only one year, 20 locations in two years, five locations in three years, and one in four years, yielding in total 96 unique location-year combinations of measurements of seasonal total flying insect biomass.  To test if weather variation could explain the observed decline, we included mean daily temperature, precipitation and wind speed in our analysis, integrating data from 169 weather stations [38] located within 100km to the trap locations.  Land use variables (and changes therein) were derived from aerial photographs [44] taken within two distinct time periods (between 1989–1994, and between 2012– 2015), and allowed us to characterize land use composition at surroundings of the traps, as well as changes over time. We distinguished cover of forests, agricultural areas, natural grassland, and surface water.  Plant inventories were conducted in the immediate surroundings (within 50m) of the trap, in the same season of insect sampling. These data permitted the assessment of plant species richness (numbers of herbs, shrubs and trees) and environmental conditions based on average Ellenberg values [46–48].  We developed a series of models each consisting of a set of explanatory variables that measure aspects of climate, land use and local habitat characteristics.  Parameter values are obtained by the use of Markov chain Monte Carlo (MCMC) methods by the aid of JAGS.  **Results**  Annual trend coefficient of our basic model was significantly negative (annual trend coefficient = −0.063, sd = 0.002, i.e. 6.1% annual decline). Based on this result, we estimate that a major (up to 81.6% [79.7–83.4%]) decline in mid-summer aerial insect biomass has taken place since 1989.  Insect biomass was positively related to temperature and negatively to precipitation.  There was substantial variation in trapped insect biomass between habitat clusters (see Materials and methods), with nutrient-rich grasslands, margins and wasteland containing 43% more insect biomass than nutrient-poor heathland, sandy grassland, and dunes. Yet, the annual rate of decline was similar, suggesting that the decline is not specific to certain habitat types.  Plant species inventories that were carried out in the immediate vicinity of the traps and in the same season of trapping, revealed that species richness of trees, shrubs and herbs declined significantly over the course of the study period.  **Discussion**  This considerably exceeds the estimated decline of 58% in global abundance of wild vertebrates over a 42-year period to 2012 [56, 57].  it is not only the vulnerable species, but the flying insect community as a whole, that has been decimated over the last few decades.  The estimated decline is considerably more severe than the only comparable long term study on flying insect biomass elsewhere [28].  Given the major decline in insect biomass of about 80%, much stronger relationships would have been expected if changes in habitat and land use were the driving forces.  While some temporal changes in climatic variables in our study area have taken place, these either were not of influence (e.g. wind speed), or changed in a manner that should have increased insect biomass (e.g temperature). However, we have not exhaustively analysed the full range of climatic variables that could potentially impact insect biomass. For example prolonged droughts, or lack of sunshine especially in low temperatures might have had an effect on insect biomass [59–62]. Agricultural intensification [17, 20] (e.g. pesticide usage, year round tillage, increased use of fertilizers and frequency of agronomic measures) that we could not incorporate in our analyses, may form a plausible cause. Almost all locations (94%) are enclosed by agricultural fields. Part of the explanation could therefore be that the protected areas (serving as insect sources) are affected and drained by the agricultural fields.  There is an urgent need to uncover the causes of this decline, and its geographical extent. | Hallmann et al., 2017 observed a seasonal decline of 76% total insect biomass from 1989 to 2016 in Germany regardless of habitat type, and the changes could not be explained by weather, land use, or habitat characteristics.  A major aim for future work is to investigate the causes of the decline, and where they have the biggest impact (Hallmann et al., 2017). |
| (Wagner et al., 2021b)  Another recent review that's worth reading to familiarise yourself with the field | 31/3/22 | **Insect decline in the Anthropocene: Death by a thousand cuts.**  Although a flurry of reports has drawn attention to declines in insect abundance, biomass, species richness, and range sizes (e.g., refs. 12–18; for reviews see refs. 19 and 20), whether the rates of declines for insects are on par with or exceed those for other groups remains unknown.  There are still too little data to know how the steep insect declines reported for western Europe and California’s Central Valley—areas of high human density and activity—compare to population trends in sparsely populated regions and wildlands. Long-term species-level demographic data are meager from the tropics, where considerably more than half of the world’s insect species occur (21, 22).  Entomological Society of America hosted a symposium at their Annual Meeting in St. Louis, Missouri, in November 2019. All 11 talks were recorded and are available on the Entomological Society of America’s website, https:// [www.entsoc.org/insect-decline-anthropocene](http://www.entsoc.org/insect-decline-anthropocene).  Insects comprise much of the animal biomass linking primary producers and consumers, as well as higher-level consumers in freshwater and terrestrial food webs. Situated at the nexus of many trophic links, many numerically abundant insects provide ecosystem services upon which humans depend: the pollination of fruits, vegetables, and nuts; the biological control of weeds, agricultural pests, disease vectors, and other organisms that compete with humans or threaten their quality of life; and the macrodecomposition of leaves and wood and removal of dung and carrion, which contribute to nutrient cycling, soil formation, and water purification. Clearly, severe insect declines can potentially have global ecological and economic consequences.  While there is much variation—across time, space, and taxonomic lineage—reported rates of annual decline in abundance frequently fall around 1 to 2% (e.g., refs. 12, 13, 17, 18, 30, and 31).  Not all insects are declining. Four papers in this special issue note instances of insect lineages that have not changed or have increased in abundance (24, 29, 32, 33).  Abundant evidence demonstrates that the principal stressors—land-use change (especially deforestation), climate change, agriculture, introduced species, nitrification, and pollution—underlying insect declines are those also affecting other organisms. Also challenged by additional stressors, such as insecticides, herbicides, urbanization, and light pollution. In areas of high human activity, where insect declines are most conspicuous, multiple stressors occur simultaneously.  Considerable uncertainty remains about the relative importance of these stressors, their interactions, and the temporal and spatial variations in their intensity.  Taking the domesticated honey bee as an example, its declines in the United States have been linked to (introduced) mites, viral infections, microsporidian parasites, poisoning by neonicotinoid and other pesticides, habitat loss, overuse of artificial foods to maintain hives, and inbreeding; and yet, after 14+ y of research it is still unclear which of these, a combination thereof, or as yet unidentified factors are most detrimental to bee health.  Essential time-series data on the rates, geographic scope, ecological aspects, and taxonomic nature of insect population trends are scant, relative to those for vertebrates.  Studies that generalize across datasets, higher taxonomic categories, or ecological groups (e.g., refs. 17, 18, 51, and 52) provide much-needed perspectives relevant to ecological function as, for example, the amount of insect food available to nestlings (53) and other insectivores or the general health of a region’s pollinators. Although data aggregation and meta-analyses are required approaches for understanding global phenomena, by their nature, they often overlook species-level trends.  Colony collapse disorder and the honey bee’s struggles with the ectoparasitic varroa mite and viral infections were among the first cases to draw global attention to insect decline.  Dirzo et al.’s (12) “Defaunation in the Anthropocene” was the first metaanalysis to report global cross-lineage insect losses for beetles, dragonflies, grasshoppers, and butterflies. Across 16 studies, insect populations had declined by 45% in the last four decades.  van Klink et al. (17, 18), examined 166 studies with demographic data spanning 9 to 80 y. Their assessment, driven largely by European and North American datasets, suggested terrestrial insects were declining at a rate close to 1% per year, while aquatic insects appeared to be increasing in abundance, again by about 1% per year.  Crossley et al.’s (51) metaanalysis of insect demographic data (spanning 4 to 36 y) for 15 long-term ecological research sites across the United States, reported no evidence of a continent wide decline of insect abundance. The entomological community is still evaluating the accuracy of these recent findings.  An important limitation of assessments based on long-term monitoring data are that they come from locations that have remained largely intact for the duration of the study and do not directly reflect population losses caused by the degradation or elimination of a specific monitoring site (although effects can be measured in a metapopulation context if the number of years sampled is sufficient in remaining sites).  It is particularly urgent to know to what degree climate change is driving losses in the tropics, in mountains, and other wildlands away from pronounced anthropogenic activity.  Despite the urgent need for data to inform evidence-based plans for mitigating or reversing decline, there exist many datasets that remain unanalyzed. | We currently do not have enough data to assume that patterns observed for Westernised countries — where most research has been focused — also applies to tropics where despite high insect biodiversity, long-term species-level data is deficient. Additionally, invertebrates are still understudied compared to vertebrates (Wagner et al., 2021b).  Furthermore, many datasets in existence remain unanalysed (Wagner et al., 2021b). Therefore, there is a need to develop new pipelines that will best utilise these.  Geography, time, and taxonomy all contribute to the wide variation that has been observed in insects (Wagner et al., 2021b).  It is also important to realise that not all insects are declining (Wagner et al., 2021b).  A major aim for future work is to investigate the causes of the decline, especially where they have the biggest impact, and any possible interactions (Wagner et al., 2021b).  Different types of studies provide a range of perspectives — for example, studies that generalise across datasets provide necessary viewpoints of the general health status of insects, though likely overlook species-level trends that more focused studies may capture (Wagner et al., 2021b). |
| (Sánchez-Bayo and Wyckhuys, 2019)  Worldwide decline of the entomofauna: A review of its drivers.  This is one of the papers where the search strategy is questionable, but there's a lot of content in there to help you get familiarised with the field. It's also worth taking a little time to read a couple of the responses! | 31/3/22  Read bits on different orders, and different drivers on 12/4/22 | **Abstract**  Comprehensive review of 73 historical reports of insect declines from across the globe, and systematically assess the underlying drivers.  Our work reveals dramatic rates of decline that may lead to the extinction of 40% of the world's insect species over the next few decades.  Affected insect groups not only include specialists that occupy particular ecological niches, but also many common and generalist species.  Concurrently, the abundance of a small number of species is increasing; these are all adaptable, generalist species that are occupying the vacant niches left by the ones declining.  The main drivers of species declines appear to be in order of importance: i) habitat loss and conversion to intensive agriculture and urbanisation; ii) pollution, mainly that by synthetic pesticides and fertilisers; iii) biological factors, including pathogens and introduced species; and iv) climate change.  **Intro**  Yet, we don't know whether the same factors explain the parallel entomological demise that we are witnessing.  **Methods**  We performed a search on the online Web of Science database using the keywords [insect\*] AND [declin\*] AND [survey], which resulted in a total of 653 publications.  **Results**  **Taxa declines -** goes through lots of different insect taxa and the trends found in various papers.  Lepidoptera - Butterflies and moths.   * Indicators of environmental quality, considering their high degree of host-plant specialisation and vulnerability to habitat deterioration. * presence in a broad range of habitats * loss may directly impact the delivery of key ecosystem services such as pollination and natural pest control * Moths constitute important prey items of bats and help sustain population levels of myriad other insectivorous animals * Maes and van Dyck (2001) were the first to report drastic changes in butterfly biodiversity in Flanders (Belgium) during the 20th century. Habitat loss, urbanisation, and agricultural intensification contributed to decline and extinction. * Van Dyck et al., 2009 – follow-up study. 11 of the 20 most common and widespread butterfly species declined both in distribution and abundance between 1992 and 2007,whereas populations of species associated with natural habitats in nature reserves remained stable. * Groenendijk and van der Meulen, 2004 - the range of distribution of 733 species of day-flying moths was recorded between 1980 and 2000: overall declines were observed in 85% of species, 38% of them experiencing > 75% reduction in their area (i.e. critically endangered). * Monophagous and oligophagous species using grass or herbs in wetlands were declining more than those feeding on deciduous trees or shrubs, confirming that dietary specialists bear the brunt of the declines. * Species with a short flight-period or those restricted to non-forest habitats were all associated with a high extinction risk * A comparison of historical records of 74 butterflies in Finland showed how 60% of grassland species declined over the past 50 years, whereas 86% of generalist species and 56% of those living at forest edge ecotones increased in abundance (Kuussaari et al.,2007). * North-eastern Spain, where yearly monitoring of 183 butterfly species over 1994–2014 permitted an in-depth analysis of population trends and associated factors for 66 species. While 15 species had increased in abundance, five remain stable and 46 are declining (Melero et al., 2016). * For the United States, long-term monitoring data of butterflies are limited * The only trait that correlated significantly with the declines was the overwintering stage of each species (Breed et al.,2012) * Although survey records are limited, Lepidoptera declines appear to be less dramatic in certain parts of the Asian region   Hymenoptera – bees, ants, wasps, and parasitoids   * Bees are essential pollinators, important for the ecosystem services they provide as well as their economic value * Status of most other hymenopterans remains practically unknown to this date * Bumblebees –   + Using foraging data on eight native bumblebees and information on their distribution, found that the species subject to the greatest reduction in distribution were host-plant specialists (Williams, 1982).   + Long-tongued bumblebees that forage on clover and other legumes, traditionally used in rotations as a source of nitrogen, had their populations curtailed after the foraging plants were steadily replaced by chemical fertilisers in southern England (Goulson et al., 2005).   + Large-scale conversion of landscapes to intensive agriculture together with unrelenting pesticide use are blamed for the changes in bumblebee biodiversity observed over the past 75 years (Bommarco et al., 2013).   + Declines were blamed on reduced floral and nesting resources, but declining populations also had greater infection rates by N. bombi and lower genetic diversity than the non-declining bee populations; some of the sharpest declines were recorded in regions dominated by intensive agriculture (Cameron et al., 2011) * Other wild bees   + Wild bees are estimated to provide at least 20% of pollination ser-vices in agricultural production (Loseyand Vaughan, 2006)   + Declining species were habitat and dietary specialists, univoltine and sedentary species in all cases, among which solitary bees were the most affected; moreover, plant species reliant on bee pollination alone were declining in both countries (Biesmeijer et al., 2006).   + As agriculture occupies 70% of land-use in Britain, a causal relationship between species decline and farm management may involve multiple factors, including habitat changes and the use of chemical fertilisers and pesticides   + A detailed analysis of the interactions between 109 pollinating bees and their host plants was studied in 26 forests of Illinois (USA), and compared to historical records for the same site from the late 1800s and early 1970s. This floral network revealed many changes over the years, with only 24% of the original pollinator-plant interactions remaining. Shifts in network structure were due to losses of individual bee species in 45% of cases (Burkle et al., 2013).   + Losses of biodiversity among wild bees are also documented for tropical regions * Honey bees   + In the USA, a peak of six million honey bee colonies was recorded in 1947 but this number has been declining ever since, with losses of 3.5 million over the past six decades at 0.9% annual rate of decline (Ellis,2012).   + The demise started immediately after the introduction of the organochloride insecticide DDT in agriculture and has since continued unabated   + Widespread parasite and pathogen infections that are becoming more virulent in recent years (Anderson et al., 2011;Yang and Cox-Foster, 2007); lack of genetic variability; stress due to seasonal movement of hives for pollinating fruit and vegetable crops (Smart et al., 2016); toxic pesticide residues found in the pollen and nectar or applied to hives for controlling Varroa mites (Johnson et al.,2013); poor nutritional value of agro-landscapes dominated by mono-cultures (e.g. corn, oilseed rape, cotton (Huang, 2012)); and finally the harsher climatic conditions of recent decades.   + The most likely explanation for the declines, however, is a combined effect derived from synergistic interactions between parasites, pathogens, toxins and other stressors (Alburaki et al., 2018; Goulson et al., 2015; Sánchez-Bayoet al., 2016b), which has resulted in the colony collapse disorder (CCD) (Underwood and vanEngelsdorp, 2007). * Formicidae – ants   + Studies are lacking apart from a few invasive species   + Tropical deforestation has been invoked as a major cause for biodiversity losses of ants and other insects at the global scale–specifically for forest-inhabiting species (Wilson, 2002).   Diptera – flies   * Hoverflies (Syrphidae) are important pollinators and key natural enemies of agricultural pests such as aphids, with a preference for damp habitats * The only long-term study to date found parallel reductions in species richness among hoverflies in the Netherlands and the U.K. (Biesmeijer et al., 2006). That migratory hoverflies fared better than their sedentary counterparts in the latter two countries suggests that mobility is an important trait for survival.   Coleoptera – beetles   * The largest order of insects includes important groups of predatory and saprophytic species that provide essential ecosystem services in pest control and recycling of organic matter among others. * Carabidae – ground beetles   + Tiger beetles (Cicindelidae) are regularly used as indicators of biodiversity   + Most of the changes among European carabids can be explained by habitat destruction, increased eutrophication due to agricultural intensification and expanding urbanisation.   + In the U.K., dramatic declines of 49 out of the 68 carabids studied at 11 sites over 15 years, led to consider 26 species as vulnerable and eight endangered, whereas 19 species appear to be either stable or even increasing. Overall, a 16% loss of carabid beetle biomass was recorded during the 15-year period (Brooks et al., 2012). Changes in biodiversity were not linear and correlated with habitat and geographical variation * Coccinellidae – ladybirds   + build-up of invasive aphid pests in agricultural crops. H. axyridisis out-competing native ladybirds in Great Britain (Roy and Brown, 2015) * Dung beetles   + unique ecological function is of vital importance to the livestock sector and for the soil fertility of grasslands.   + Studies on the decline of these specialized beetles are available only for the Mediterranean region * Saproxylic beetles   + Major role in decomposition of wood in ecosystems, thus recycling nutrients that would otherwise be locked in decay logs and branches. Some species are also involved in pollination.   + In Europe, logging, wood harvesting and agricultural expansion have caused losses of old native forests, thus threatening the survival of56 species of saproxylic beetles (a third of them endemic)   Hemiptera – "true bugs" e.g. cicadas, aphids, planthoppers, leafhoppers, bed bugs, and shield bugs   * One study of planthoppers and leafhoppers (Auchenorrhyncha) in protected grasslands of Germany was found (Schuch et al., 2012). Overall species richness did not change. However, species composition changed considerably, with 14 species declining (mostly specialists) and nine others increasing (mostly generalists), while one species (Zyginidia scutellaris) characteristic of acidic grasslands became very dominant.   Orthoptera - grasshoppers, locusts, and crickets   * A single long-term study on grasshoppers and crickets is available, conducted at the same German sites as above (Schuch et al., 2011). Their biodiversity in protected grasslands did not change over four decades (median 9 species per site), and changes in species assemblages were small.   Odonata – dragonflies and damselflies   * Both nymphs and imagos are predators of aquatic organisms and flying insects respectively, and they play an important role in controlling nuisance mosquitoes and agricultural pests * In the USA, recent surveys at 45 sites across California and Nevada were compared to historical records from 1914 to 1915. Occurrence rates of 52 species of dragonflies and damselflies (65% of all recorded)have declined over the 98-year period while those of 29 species have increased. Two generalist and pollution-tolerant species that were not recorded in 1914–1915 greatly expanded their range into California and became common, particularly in urban areas. (Ball-Damerow et al., 2014) * While species richness has not declined, Odonata assemblages have become more homogeneous in species composition, which is typically an effect of urbanisation (McKinney, 2006).   Other freshwater taxa   * Freshwater insect taxa tend to have rather inflexible life cycles, with many species being univoltine (one brood of offspring per year), thus making them particularly sensitive to habitat change. Flow alterations, habitat fragmentation, pollution and invasive species are the main threats to all aquatic organisms, including insects   **Discussion**  This review brings to the fore the demise of major insect taxa (albeit no studies are available for most Diptera, Orthoptera and Hemiptera), which started at the dawn of the 20th century, accelerated during the1950s–1960s, and attained alarming proportions globally over the last two decades.  From our compilation of published scientific reports, we estimate the current proportion of insect species in decline (41%) to be twice as high as that of vertebrates, and the pace of local species extinction (10%) eight times higher.  At present, about a third of all insect species are threatened with extinction in the countries studied (Table 1). Moreover, every year about 1% of all insect species are added to the list, with such biodiversity declines resulting in an annual 2.5% loss of biomass worldwide.  **Drivers of the declines** – goes through lots of different reasons.  Habitat change   * A large proportion of studies (49.7%) point to habitat change as the main driver of insect declines * immediate consequence of human activities * increasing amounts of land being transformed to provide dwellings, facilitate transportation and enable tourism (urbanisation), grow food (agriculture) and manufacture goods (industrialisation) * Includes land-use change and landscape fragmentation * As agricultural crops comprise about 12% of the total land surface on the planet (FAO, 2015), farming directly affects a considerable proportion of insect species (Dudley and Alexander, 2017) * Major insect declines occurred, however, when agricultural practices shifted from traditional, low-input farming style to the intensive, industrial scale production brought about by the Green Revolution (Bambaradeniya and Amerasinghe, 2003; Ollerton et al., 2014). The latter practices did not necessarily involve deforestation or habitat modification (e.g. grassland conversion, drainage of wetlands) but rather entailed the planting of genetically-uniform monocultures, the recurrent use of synthetic fertilisers and pesticides, the removal of hedgerows and trees in order to facilitate mechanization, and the modification of surface waterways to improve irrigation and drainage   Pollution   * Sources of environmental pollution include fertilisers and synthetic pesticides used in agricultural production, sewage and landfill leachates from urbanised areas and industrial chemicals from factories and mining sites * Intensive agriculture implies the systematic and widespread use of pesticides for controlling crop pests (insecticides), competing weeds (herbicides) and fungal infections (fungicides) * Apart from pesticides, the introduction of synthetic fertilisers early in the 20th century is recognised as a key driver of pollinator losses in the U.K. and Europe (Ollerton et al., 2014), particularly among specialist bumblebees.   Biological Factors   * Parasites and pathogens are definitively involved in the collapse of honeybee colonies in various countries (Goulson et al., 2015) and also appear associated with the declining wild bees in North America (Thorpand Shepherd, 2005). * Varroa destructor mite and the small hive beetle (Aethina tumida) pose a real concern for the apicultural industry because they transmit viral infections (van Engelsdorp et al., 2012) * However, pathogens have historically co-existed with managed bee colonies: their recent virulence is more likely to have been fostered by the exposure of bees to pesticide-contaminated pollen and nectar (Long and Krupke, 2016) that weakens their immune system (Sánchez-Bayo et al., 2016b; Tesovnik et al., 2017). * The human-assisted introduction of exotic species for biological control can contribute to a decline of endemic insects through processes such as competitive displacement (Roy and Brown, 2015), or direct predation and parasitism (Boettner et al., 2008; Henneman and Memmott, 2001). Though biological control can help cut insecticide pollution in agricultural environments   Climate Change   * might positively impact on their abundance in temperate regions as they exhibit superior thermal tolerance which - in turn - may benefit their development (Deutsch et al., 2008). * In contrast, insects of tropical regions have more narrow thermal thresholds and are particularly susceptible to temperature increases.   **Conclusions**  The information presented here refers mostly to developed countries of Europe and North America (Fig. 1) since those regions have the most comprehensive historical records that allow comparisons of biodiversity on a temporal scale. | Sánchez-Bayo and Wyckhuys (2019) estimate alarming rates of decline that they predict will lead to the extinction of 40% of the world’s insect species within a few decades.  Don’t actually say it – but basically did vote counting using 73 historical reports.  It is likely that common and generalist species will be affected alongside habitat and food specialists (Sánchez-Bayo and Wyckhuys, 2019). Nevertheless, the increase in some adaptable, generalist species cannot be ignored (Sánchez-Bayo and Wyckhuys, 2019) and should be studied to observe traits that contribute to survival despite the increasing threats.  Lepidoptera: pollination, natural pest control, prey items. Hymenoptera: bees for pollination and economic value. Diptera: pollinators, natural enemies of agricultural pests. Coleoptera: pest control and recycling of organic matter. Hemiptera: true bugs. Orthoptera: grasshoppers, locusts, crickets. Odonata: dragonflies and damselflies. Control mosquitos and agricultural pests.  Sánchez-Bayo and Wyckhuys (2019) compared invertebrate to vertebrate decline, concluding the current proportion of insects in decline is twice as high as it is for vertebrates.  Nearly half of the studies reviewed by Sánchez-Bayo and Wyckhuys (2019) indicated habitat change to be the largest contributor to insect declines. |
| (Simmons et al., 2019) | 31/3/22 | Published in response to (Sánchez-Bayo and Wyckhuys, 2019).  We welcome this detailed focus on insect declines: their consistent underrepresentation is a shortcoming of the ecological literature, and it is essential that we improve and synthesize our knowledge, particularly given widespread anthropogenic threats.  Inclusion of [declin\*] as a required search term biases their evidence toward surveys that report population declines. Incorporating studies into the review which report increasing or stable populations could alter its conclusions about average trends.  Second, the acknowledged geographic bias toward North America and Europe means it is not appropriate to title the paper “Worldwide declines.” It is unlikely that insect declines will be homogenous everywhere.  Local declines of 80% over a century, for instance, should not be equated with global declines of 80% within the last ten years.  Finally, the authors attributed the trends to different threats using information from the original studies. Causal threats are challenging to identify, and some of the reported threats are simply postulated, rather than explicitly tested.  Although polling papers for their suggestions of causes of decline is valuable, it is not the same as synthesizing quantitative evidence. | Simmons et al., 2019 highlight some key issues with the Sánchez-Bayo and Wyckhuys (2019) paper: their search strategy was biased towards finding studies which report insect declines due to [declin\*] being a requirement; the study findings cannot be extrapolated globally as they are based mainly on studies conducted in North America and Europe; and the threats identified are simply stated, rather than being statistically tested. |
| (Powney et al., 2019)  There's been a few recent papers looking at changes in occupancy in the UK, where there are more extensive data | 1/4/22 | **Widespread losses of pollinating insects in Britain.**  **Abstract**  Large-scale evidence on species-specific trends among wild pollinators are lacking.  Here we show substantial inter-specific variation in pollinator trends, based on occupancy models for 353 wild bee and hoverfly species in Great Britain between 1980 and 2013.  We estimate a net loss of over 2.7 million occupied 1 km2grid cells across all species. Declines in pollinator evenness suggest that losses were concentrated in rare species.  In addition, losses linked to specific habitats were identified, with a 55% decline among species associated with uplands. This contrasts with dominant crop pollinators, which increased by 12%, potentially in response agri-environment measures.  **Intro**  Insect pollinators are vital for the maintenance of ecosystem health and for global food security.  Key threats to pollinators include agricultural intensification (particularly habitat loss and pesticide use), climate change and the spread of alien species.  Despite their importance, there is a critical absence of robust large-scale, species-specific estimates of distribution change for pollinating insects, in particular bees and hoverflies, which are considered some of the most important pollinators.  Published data on species-specific trends are currently only available from field-scale experiments typically spanning short time periods(<5 years) and spatially restricted to a limited number of sites.   * Combine these kinds of studies using my database/framework   Biological records tend to be collected by large networks of volunteer recorders, they lack a standardized protocol and thus contain sampling bias. Considerable statistical issues need to be overcome if they are to be used for detecting genuine signals of change.  Here we take advantage of recent analytical developments to construct hierarchical Bayesian occupancy detection models for 353 hoverfly and bee species, based on 715,392 biological records.  Our models estimate the proportion of occupied1 km grid squares (henceforth occupancy) each year and are designed to account for incomplete and biased sampling in the raw data.  **Methods**  Occurrence data suffered from temporal bias, with greater numbers of records in recent years. A host of techniques have been proposed to account for such bias while estimating trends, with recent studies suggesting hierarchical occupancy, models fitted within a Bayesian framework perform particularly well.  We used a Bayesian occupancy modelling approach based on the models of refs.17and31, to estimate occupancy (the proportion of occupied 1 km grid cells) each year between 1980 and 2013 for each species.  **Results**  Species-level trends, calculated as the annual growth rate in occupancy (percent change per year between the first and last year), reveal that a third of wild pollinator species (33%) have decreased over this period, approximately a tenth have increased, with the remaining species showing no clear trend.  The direction and magnitude of the species-specific trend estimates, equate to a loss (net change) of 11 pollinator species (4 bees and 7 hoverflies) per 1 km grid cell between 1980 and 2013. Extrapolating these patterns to the whole of Great Britain (~240,000 1 km grid cells), our results estimate a net loss of over 2.7 million occupied 1 km grid cells for pollinator species between 1980 and 2013.   * Can you extrapolate like this?   We found similar overall declines for bees (25% decline; 95% credible interval (CI): 21% to30% decline;n=139 species) and hoverflies (24% decline; 95%CI: 20% to 28% decline;n=214), although there are marked differences between these two groups in the temporal pattern of declines (Fig.2and Supplementary Figure 2). Virtually all severe declines observed for overall bee occupancy occurred post 2007. By contrast, hoverflies declined steadily from 1987 to 2012.  There are several key functional and ecological differences between bees and hoverflies, which could explain this pattern. Notably, most bees are fixed-place foragers whose early life stages are sheltered and actively provisioned by adults, whereas hoverflies move freely across landscapes and have juvenile stages filling a range of niches (e.g., aphidophagous, phytophagous, and detritivore) that are not directly cared for by adults.  Although most bee species declined, this was not the case for the subset of species identified as being key pollinators of a range of economically important European crops14(Supplementary Figure 3). On average, occupancy increased for these dominant crop pollinators by12% (95% CI: 1% to 23%) from 1980 to 2013. In addition, we found notable changes in the eusocial bee species (including the bumblebees) (Supplementary Figure 4), for whom average occupancy increased by 38% (95% CI: 20% to 58%) compared with a decline of 32% (95% CI: 27% to 36% decline) for solitary bees.  The apparent vulnerability of upland species may reflect retractions of the trailing (southern) range edges in response to climaticwarming25. | Powney et al. (2019) studied wild bees and hoverflies in the UK using occupancy models between 1980 and 2013. The results indicated that a third of species have decreased, a tenth have increased. Rare species fared worse, and habitat influenced the decline — 55% decrease in species associated with uplands, 12% increase in dominant crop pollinators. All severe declines in bees occurred since 2007, whereas hoverflies have experienced sustained steady declines from 1987 to 2012.  There has been increasing focus on insects in recent years, with more records collected, though studies do tend to suffer from a lack of a standardised protocol, along with geographic and temporal restrictiveness (Powney et al., 2019). |
| (Outhwaite et al., 2020)  Complex long-term biodiversity change among invertebrates, bryophytes and lichens.  Another recent change in occupancy paper | 1/4/22 | **Abstract**  Terrestrial insects and the bryophytes and lichens group increased in average occupancy.  Our results suggest a more complex pattern of biodiversity change in the United Kingdom than previously reported.  **Intro**  Most invertebrates do not feature in studies of large-scale biodiversity trends2,5, and it is unclear whether these well-studied groups reflect changes in wider biodiversity6–8. Invertebrates and plants constitute a substantial portion of biodiversity and support many ecosystem functions, so their lack of representation could mean that important trends are being overlooked.  There is thus an urgent need to mobilize existing data and interrogate them with modern, rigorous analysis tools.  Here, we use recent advances in occupancy modelling techniques that address these concerns (Biases resulting from the unstandardized nature of the data collection22–24.) and have enabled a wider range of occurrence-record datasets to be analysed.  We explore long-term changes in UK biodiversity through an analysis of the average annual occupancy of invertebrate groups, bryophytes and lichens over a 45-year period. Occupancy refers to the proportion of 1 km2 grid cells in which a species is present.  **Results**  Estimates are derived from hierarchical Bayesian occupancy-detection models for each species and are based on 24,090,792 presence-only biological records.  Across all 5,214 species, an index of overall occupancy, estimated as the geometric mean occupancy, was 11% higher in 2015 than in 1970 (95% credible interval: 9%, 13%), contradicting the narrative that declines are pervasive. However, there were substantial differences among major groups.  For both the insects and the bryophytes and lichens, the rare species showed greater changes in occurrence than the common species.  Although the mean change in occupancy is an increase of 11%, there are species that have undergone substantial declines (some of which started out relatively common), as well as initially rare species that have increased markedly over time.  Determining the drivers of change and those species most likely to exhibit strong responses will aid in the mitigation of future losses.  **Discussion**  On the basis of widely reported declines in the abundance of UK birds31 and butterflies3, and of other taxa globally2,32, one might expect to see declines in occupancy, but our results confound this expectation.  Not only is the overall net change positive; the direction of change is different among groups, and there is enormous variation among taxa in the temporal patterns of change and the relative fates of rare and common species.  It is well established that major trans-formations of the UK landscape occurred during the middle parts of the 20th century39,40, so care is needed to avoid the pitfalls of shifting baseline syndrome41,42. The values from 1970 must not be seen as targets to be reached, since it is likely that levels in 1970 were also considerably lower than earlier in the century.  Our results demonstrate the insights that can be gathered from careful analysis of presence-only occurrence records. However, they raise questions about how trends in occupancy should be interpreted in the context of more widely used metrics, such as changes in abun-dance2, species richness44, biomass10,45 or other measures of range size46,47. For example, changes in total abundance48, in total biomass10 or in average species abundance3,31 measure similar, but subtly different, facets of biodiversity. | Outhwaite et al. (2020)’s findings that terrestrial insects increased in average occupancy by 5.5% in the UK from 1970 to 2015 go against findings of many studies.  It is important that future research makes best use of existing data by analysing it with up-and-coming research methods (Outhwaite et al., 2020).  Insects under-represented in large-scale BD trend studies.  Rare species show greater change.  Determining drivers will aid mitigation of future losses.  Need to consider shifting baseline syndrome. |
| (VanEngelsdorp et al., 2009)  If you're not already, useful to be aware at least of colony collapse disorder in honey bees | 1/4/22 | **Colony Collapse Disorder: A Descriptive Study.**  **Abstract**  Over the last two winters (2006/7/8), there have been large-scale, unexplained losses of managed honey bee (ApismelliferaL.) colonies in the United States. In the absence of a known cause, this syndrome was named Colony Collapse Disorder (CCD) because the main trait was a rapid loss of adult worker bee.  Of 61 quantified variables (including adult bee physiology, pathogen loads, and pesticide levels), no single measure emerged as a most-likely cause of CCD.  **Results**  CCD-affected apiaries contained 3.5 times the number of dead colonies compared to control apiaries.  in CCD apiaries there was an increased risk of colonies being weak or dead when they neighbored other weak or dead colonies (Table 5). This suggests that CCD is either a contagious condition or results from exposure to a common risk factor.  **Discussion**  While no single pathogen or parasite was found with sufficient frequency to conclude a single organism was involved in CCD, pathogens seem likely to play a critical (albeit secondary) role. CCD colonies generally had higher virus loads and were co-infected with a greater number of disease agents than control colonies. | Honey bees are known to suffer from colony collapse disorder, which involves the loss of worker bees. No single driver is thought to be responsible, though pathogens appear to play a major role (VanEngelsdorp et al., 2009). |
| (Deutsch et al., 2008)  One of the important papers for thinking about climate change effects on insects | 1/4/22 | **Impacts of climate warming on terrestrial ectotherms across latitude.**  **Abstract**  We integrate empirical fitness curves describing the thermal tolerance of terrestrial insects from around the world with the projected geographic distribution of climate change for the next century to estimate the direct impact of warming on insect fitness across latitude.  The results show that warming in the tropics, although relatively small in magnitude, is likely to have the most deleterious consequences because tropical insects are relatively sensitive to temperature change and are currently living very close to their optimal temperature.  In contrast, species at higher latitudes have broader thermal tolerance and are living in climates that are currently cooler than their physiological optima, so that warming may even enhance their fitness.  **Results**  Insects are the largest group of terrestrial organisms.  The impact of temperature on intrinsic rates of population growth (r), a direct measure of Darwinian fitness, has been quantified experimentally for numerous insect species from around the globe (15). We use these data to construct fitness curves for each species to calculate the fractional change in population growth rate from the observed climate of the late 20th century (1950–1990) (19) to a model simulated climate (20) of the late 21st century (2070–2100), where climate data were taken at the source site of each species.  After a century of warming, population growth rates of insects change dramatically and exhibit a conspicuous latitudinal trend (Fig. 1). At mid- to high-latitudes, population growth rates are predicted to increase, indicating enhanced population fitness because of warming. In the tropics, however, intrinsic rates of population growth are expected to decrease by up to 20%, implying that warming will substantially reduce fitness.  The warming tolerance of tropical insects is, on average, only one-fifth that of mid-latitude insects.  **Discussion**  Acclimation, adaptation, dispersal, and behavioral plasticity will all help mitigate the adverse impacts of climate change but are unlikely to completely offset the decreased fitness predicted here for tropical organisms.  This conclusion is troubling because it places the greatest biological risks of climate change in the tropics where biodiversity is greatest. | Climate change affects intrinsic rates of population growth. It is predicted that tropical insects will suffer more due to the warming tolerance of tropical insects being, on average, a fifth of that of higher-latitude insects. This makes tropical insects particularly sensitive to increases in temperature, especially considering they are currently living close to their thermal optimum. It is also especially concerning seeing as biodiversity is greatest in the tropics (Deutsch et al., 2008). |
| (Biesmeijer et al., 2006)  Another important empirical paper | 1/4/22 | **Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands.**  **Abstract**  By studying bee and hoverfly assemblages in Britain and the Netherlands, we found evidence of declines (pre- versus post-1980) in local bee diversity in both countries; however, divergent trends were observed in hoverflies.  Pollinator declines were most frequent in habitat and flower specialists, in univoltine species, and/or in nonmigrants.  In conjunction with this evidence, outcrossing plant species that are reliant on the declining pollinators have themselves declined relative to other plant species. Taken together, these findings strongly suggest a causal connection between local extinctions of functionally linked plant and pollinator species.  **Main body**  Substantial concerns have been raised about the decline or loss of these services. However, the evidence for such declines remains scanty (5).  We then applied rarefaction methods to compare species richness of focal areas over each period.  Bee diversity declined in large fractions of the 10 km by 10 km cells analyzed in both countries (Fig. 1). Bee richness was measured as the number of distinct species; significant decreases in richness were observed in 52% and 67% of British and Dutch cells, respectively, as compared with richness increases in 10% and 4% of cells in the two countries.  Shifts in hoverfly diversity were less consistent (Fig. 1), with no significant directional change in richness for the UK (increases in 25% and decreases in 33% of British cells); however, increases in hoverfly richness were reported in 34%, versus decreases in 17%, of Dutch cells.  Our data set does not allow direct measurement of population densities of the species involved.  There has been an increase in the domination of the pollinator communities of both countries by a smaller number of species.  In both countries and in both groups, species with narrow habitat requirements have experienced greater relative declines.  Such shifts in pollinator traits suggest possible shifts in pollination services. Indeed, recent experiments have shown that the functional diversity of pollinators can affect diversity in plant communities (12).  Bee-dependent plants have declined, abiotically pollinated plants have increased, and plants mainly relying on self-pollination have shown an intermediate response. We cannot tell from these data whether the decline of the plants precedes the loss of the associated pollinators, whether the decline of the pollinators leads to the loss of reproductive function and then to the decline of the plants, or indeed whether the plants and their pollinators are both responding to some other factor. | Biesmeijer et al. (2006) found significant decreases in bee richness observed in 52% and 67% of British and Dutch cells, respectively. This was based on rarefaction methods applied before and after 1980. They also observed increased in 10% and 4%, respectively. Hoverflies showed no significant change in the UK, but increases in 34% and decreases in 17% of Dutch cells.  Declines were more frequent in habitat/food specialists, univoltine species, and/or nonmigrants, and the changes led to an increase in domination by a smaller number of species. |
| (Ollerton et al., 2014) | 14/4/22 | **Extinctions of aculeate pollinators in Britain and the role of large-scale agricultural changes.**  **Abstract**  Using historical records, we assessed the rate of extinction of bee and flower-visiting wasp species in Britain from the mid-19th century to the present.  The most rapid phase of extinction appears to be related to changes in agricultural policy and practice beginning in the 1920s, before the agricultural intensification prompted by the Second World War, often cited as the most important driver of biodiversity loss in Britain.  Slowing of the extinction rate from the 1960s onward may be due to prior loss of the most sensitive species and/or effective conservation programs.  **Main body**  Here we assess the bee and flower-visiting wasp species that have gone extinct in Britain, using 494,117 records held by the Bees, Wasps and Ants Recording Society (BWARS), probably the most detailed available for a single country.  Twenty-three bee and flower-visiting wasp species have become extinct in Britain (Table 1), including formerly widespread species.  Some of the phases of acceleration in the rate of species loss coincide with large-scale changes in agricultural policy and practice in Britain.   * Correlational, not causational   For example, the second half of the 19th century saw the increased import of South American guano as soil fertilizer (11), which had double impact on bee and wasp floral resources: (i) increased grass productivity at the expense of wild flower diversity (12); and (ii) decline in reliance on strict rotational cropping.  Additionally, during the late 19th and early 20th centuries, the area of arable and fodder crops declined by more than 55%, replaced by permanent grassland.  After World War I, food security concerns led to agricultural reforms that further intensified farming in Britain. This was aided by the invention of the Haber process, allowing the industrial manufacture of inorganic nitrogen fertilizers (14) and probably accelerating the decline of wild flowers (12).  The third phase from the late 1920s to the late 1950s can be attributed to agricultural intensification after World War I and during and after World War II, marking the greatest loss of bees and wasps at 3.41 to 3.46 species per decade.  The period from the late 1950s to the mid-1980s showed a slowing of the extinction rate to ~0.98 species per decade (Table 2), which is not easily explained in light of intensification of farming encouraged by Common Agricultural Policy subsidies.  Agriculture accounts for 70% of British land use, strongly suggesting that this relationship is causal, though the exact drivers of extinctions are clearly multifactorial and complex. | (Ollerton et al., 2014) used historical records to assess the extinction rate of bee and flower-visiting wasp species in Britain. They inferred that the greatest decline of nearly 3.5 species per decade in the 1920s to 1950s coincided with intensification of agricultural practice. Following this, roughly 0.98 species were loss per decade. |
| (Cardoso et al., 2020) | 14/4/22 | **Scientists' warning to humanity on insect extinctions**  **Abstract**  Here we build on the manifesto ‘World Scientists’ Warning to Humanity, issued by the Alliance of World Scientists. As a group of conservation biologists deeply concerned about the decline of insect populations, we here review what we know about the drivers of insect extinctions, their consequences, and how extinctions can negatively impact humanity.  We are causing insect extinctions by driving habitat loss, degradation, and fragmentation, use of polluting and harmful substances, the spread of invasive species, global climate change, direct overexploitation, and co-extinction of species dependent on other species.  With insect extinctions, we lose much more than species. We lose abundance and biomass of insects, diversity across space and time with consequent homogenization, large parts of the tree of life, unique ecological functions and traits, and fundamental parts of extensive networks of biotic interactions. Such losses lead to the decline of key ecosystem services on which humanity depends. From pollination and decomposition, to being resources for new medicines, habitat quality indication and many others, insects provide essential and irreplaceable services.  We appeal for urgent action to close key knowledge gaps and curb insect extinctions.  **Intro**  Until recently, we were largely unaware that insects could be imperilled to such an extent.  It is not only their vast numbers, but the dependency of ecosystems and humanity on them, that makes the conservation of insect diversity critical for future generations.  Alliance of World Scientists (Ripple et al., 2017). The latter warning was signed by over 15,000 scientists and claims that humans are “pushing Earth's ecosystems beyond their capacities to support the web of life.”  **We are causing insect extinctions**  Yet, in order to act, we first need to identify and quantify the different ways we are acting upon them, recognizing that much is still to be understood, and more often than not, several factors contribute synergistically to decline or extinction.  Habitat loss and fragmentation   * agroeconomic pressure for land * deforestation, agricultural expansion, and urbanization * Habitat loss is often accompanied by habitat fragmentation, and both lead to decreasing connectivity * In these times of global warming, habitat connectivity becomes increasingly important for all insect survival. This is because insect range shifts in response to climate change are often constrained by insufficient habitat connectivity in fragmented landscapes (Platts et al., 2019), and so lag behind the increase in temperature, even for mobile species (Devictor et al., 2012; Termaat et al., 2019).   Pollution   * Pesticides are key drivers of insect declines due to their intensive use * Pesticides impact insect populations via direct toxicity and sub-lethal effects (mainly insecticides), and indirectly through habitat alteration (mainly herbicides) * Many fertilizers (including organic and mineral fertilizers) widely used in agriculture, can affect insect populations indirectly, via impacts on the composition or quality of plant resources, on structural habitat properties or causing soil acidification, and through eutrophication * Industrial pollution (including air pollution, chemicals from factories or mining operations, and heavy metals) also causes insect population declines (Zvereva and Kozlov, 2010). * Industrial discharge, sewage, and agricultural and urban run-off as well as increased sediment deposition, all reduce freshwater habitat quality * Light pollution - Nocturnal insects are especially vulnerable to changes in natural light/ dark cycles   Invasive species   * Impacts may be direct (e.g., through predation, competition, or disease vectoring) and/or indirect (e.g., through trophic cascades, co-extinction of herbivore or parasitoid hosts). * Species introductions may ultimately lead to local loss of native insects, with those exhibiting narrow geographic distributions or specialist feeding habits being most vulnerable * The monotypic nature of invasive plants reduces the quantity and/or quality of food, and leads to declines in essential resources for many insects   Climate change   * Leads to a variety of multifaceted ecological responses to environmental changes, including shifts in species distribution ranges (Chen et al., 2011), phenological displacements (Forrest, 2016), novel interactions among previously isolated species (Krosby et al., 2015), extinctions (Dirzo et al., 2014), and other unpredictable cascading effects at different levels of ecosystem organisation (Peñuelas et al., 2013).   Overexploitation   * Unsustainable harvesting for use as pets and decoration (as souvenirs and jewels), or as food resources and traditional medicine   Co-extinction   * Specialisation has led to many insects becoming co-dependent, and therefore, vulnerable to co-extinction (Dunn, 2005; Dunn et al., 2009). Among these, numerous insect lineages have diversified with vertebrates, either as parasites, epizoic mutualists, or commensal coprophages   **We lose much more than species**  Abundance and biomass   * Large declines in abundance have also occurred among UK butterflies and moths (Conrad et al., 2004, 2006; Thomas et al., 2004; Shortall et al., 2009; Fox, 2013; Knowler et al., 2016; Storkey et al., 2016), dragonflies (Clausnitzer et al., 2009) and carabid beetles (Brooks et al., 2012) in recent years. * Negative trends are not restricted to Europe, but also occur in other parts of the world (Wagner, 2019). * A global meta-analysis of insect abundances revealed a 45% decline across two-thirds of the taxa evaluated (Dirzo et al., 2014). Yet, the specific trend and strength of the decline or eventual increase is not universal and changes according to taxon and region. * Biomass is a measurement of the amount of energy flowing through trophic levels that insects represent. In turn, reduced abundance and biomass affects ecosystem functionality and resilience, food web structure, and species interactions, such as plant-pollinators, population persistence, and many ecosystem service. * While insect conservation often target charismatic, rare, or threatened species, the temporal and spatial trends of common and widespread species are often overlooked (Gaston, 2011). Numerical declines of common and widespread species impact the functioning of ecosystems more severely.   Differences in space and time   * Insect assemblages tend to be composed of few very common and many rare species. In a forest, we find soil, ground active, undergrowth, sub-canopy, and canopy species. High levels of beta-diversity. * Research tends to describe overall arthropod richness and compositional changes driven by the common species. Given their nature, it is much harder to quantify how rare species are responding to anthropogenic pressures (van Schalkwyk et al., 2019). * Processes that homogenise natural systems decrease beta-diversity by removing rare species from the system.   Phylogenetic diversity   * Insects constitute a major branch of the tree of life, representing ca. 480 million years of evolution (Misof et al., 2014). Preserving this phylogenetic diversity is crucial to protect the evolutionary trajectories of the most successful taxonomic group on our planet.   Functional diversity   * Functional diversity provides a direct link between biodiversity and ecosystem processes. Moreover, loss of particular traits can result in changes to key ecological processes promoted by insects, such as pollination (Saunders, 2018) and decomposition (Barton and Evans, 2017) * Threatened species are not a random subset of all the species. Threatened species tend to share biological traits that influence their extinction risk (Chichorro et al., 2019). * In general, specialists in either habitat type or feeding regime, very small or very large species, and poor dispersers, are at highest risk.   Ecological networks   * Insect extinctions not only reduce species diversity, but also simplify networks   **We depend on insects**   * Insects contribute to the four main types of ecosystem services defined by the Millennium Ecosystem Assessment (2003): i) provisioning services, ii) supporting services, iii) regulating services, and iv) cultural services   **We need immediate action**   * Existing data on insect population trends and drivers have several problems (Cardoso and Leather, 2019), yet it is possible to minimize them by taking advantage of multiple datasets. * Published data from scientific papers or grey literature, online sources, such as the Predicts or Biotime databases, primary data from museum collections, as well as multiple citizen science projects could be collated to better understand richness, abundance, and composition data on insects across space and time. | Along with species, we also lose abundance, biomass, diversity, unique functions, traits, and services and end up with more homogenised communities and networks with weaker and fewer connections (Cardoso et al., 2020).  Habitat loss and fragmentation, pollution, invasive species, climate change, over-exploitation, often acting synergistically (Cardoso et al., 2020). But there is still much to be understood.  We tend to see specialist, rare species faring worse than common species, though it has been highlighted that this could be due to rarer species being harder to monitor. Additionally the trends are rarely universal and display much variation both geographically and temporally. If common species are also declining, this could have much stronger impacts on ecosystem functioning (Cardoso et al., 2020).  Major branch of tree of life, most successful taxonomic group on our planet.  Traits are extremely important for inclusion in future studies to determine the traits that increase extinction risk. So far, it is believed that specialists, very small or very large species, and poor dispersers are particularly prone to extinction, though by combining and analysing multiple datasets, we could get a better idea of this (Cardoso et al., 2020). |
| (Hallmann et al., 2020) | 14/4/22 | **Declining abundance of beetles, moths and caddisflies in the Netherlands**  **Abstract**  We present the results of longer-term insect monitoring from two locations in the Netherlands.  Based on data from insects attracted to light in De Kaaistoep, macro-moths (macro-Lepidoptera), beetles (Coleoptera), and caddisflies (Trichoptera) have declined in the mean number of individuals counted per evening over the period of 1997–2017, with annual rates of decline of 3.8, 5.0 and 9.2%, respectively.  Other orders appeared stable [true bugs (Hemiptera: Heteroptera and Auchenorrhyncha) and mayflies (Ephemeroptera)] or had uncertainty in their trend estimate [lacewings (Neuroptera)].  Based on 48 pitfall traps near Wijster, ground beetles (Coleoptera: Carabidae) showed a mean annual decline of 4.3% in total numbers over the period of 1985–2016. Nonetheless, declines appeared stronger after 1995.  For macro-moths, the mean of the trends of individual species was comparable to the annual trend in total numbers. Trends of individual ground beetle species, however, suggest that abundant species performed worse than rare ones.  When translated into biomass estimates, our calculations suggest a reduction in total biomass of approximately 61% for macro-moths as a group and at least 42% for ground beetles, by extrapolation over a period of 27 years.  **Intro**  Information on the abundance and trends of insects is largely lacking, and/or is geographically limited, preventing the assessment of their state in the landscape.  large-scale monitoring data exist usually only for species such as butterflies (Van Dyck et al., 2009; van Strien et al., 2019), dragonflies (Termaat et al., 2015; 2019), bees (Biesmeijer et al., 2006; Aguirre-Gutierrez et al., 2016) and moths (Groenendijk & Ellis, 2011; Habel et al., 2019b), taxonomically limiting the inference that can be made over the state entomofauna in general.  **Methods**  *Collecting at light in De Kaaistoep*  To analyse trends for each order (or species) k, we modelled the counts in year t and on day d using generalised additive models (GAMs; Wood, 2006) and assuming a negative-binomial distribution (White & Bennetts, 1996) and a log link to the predictors. GAMs were deemed more appropriate than generalised linear models, as insects counts vary considerably throughout the year, often with multiple peaks (i.e. generations), as well as between years (i.e. nonlinear dynamics).  The different models were compared by the Akaike’s information criterion (AIC)  *Pitfall traps near Wijster*  We used GAMs to model the annual community abundance and counts per species (based on annual totals) with a negative-binomial distribution and a log link. We treated trap location as a random effect by making use of the random effects as smooth terms  *Biomass estimation*  Insect monitoring at De Kaaistoep and Wijster is based on counts of individuals per species or higher taxa, while weighing of insects is not part of the monitoring protocol. Yet, we deemed it interesting to try to compare our abundance trends to recent findings of insect biomass declines in Germany (Hallmann et al., 2017).  **Results**  Following correction for sampling duration and weather effects, and based on the overall mean (linear) estimates, true bugs (Hemiptera-Heteroptera and Hemiptera-Auchenorrhyncha) appeared to be stable, and lacewings (Neuroptera) appeared to decline but not significantly so, and hence their trend was considered to be uncertain. In contrast, caddisflies (Trichoptera), mayflies (Ephemeroptera), beetles (Coleoptera) and moths (macro-Lepidoptera) showed significant negative coefficients.  In total, 156 species of ground beetles were found in the pitfall traps. Year totals of specimens over all species of ground beetles showed a declining pattern regardless of the considered model.  Among 127 ground beetle species with sufficient data, the average of the species trends (based on year totals) amounted to a 7% decline per year.  Most species (42.5%) showed declining (most of which severe declines) trends, while 29.4% of the species showed stable or uncertain trends and 8.5% of species showed significantly positive trends.  Considering only the period after 1995, the rate of decline in biomass appeared a lot more severe (ρ = −0.0414, se = 0.006, P < 0.001), implying an on average 4.1% (se = 0.53) decline per year.  **Discussion**  Since only two areas are included in this analysis, it is hard to generalise to the national level, and we urge caution with extrapolating conclusions from these results to broader spatial level.  Since no relation was found between weight of the species and their annual trend, we conclude that the biomass reduction (−3.3% per year) is shared proportionally among macro-moth species, with declines in abundant species naturally accounting for a larger extent of the biomass decline.  Annual decline in total biomass of ground beetles (based on pitfall data), however, was less negative than the average of the individual species trend (totals −6%, mean species trend −7%, biomass −4%). Additionally, following corrections of several traits, a positive effect was found of weight on species trend (Fig. 7c). Here, the less abundant and smaller species showed stronger declines than common or larger species, giving rise to a much lower decline rate in biomass as compared to the numerical declines.  These results imply that the declines in insect biomass, although indicative to diversity loss, may not always show a one-to-one correspondence to numerical declines (Homburg et al., 2019).  Identifying causes of insect population change was beyond the scope of this study.   * Metanalyses can do way more than an individual study can do alone   Over an extrapolated period of 27 years, this amounted to a reduction of 61%, which is close to (but less than) the reported declines in Germany for total flying insect biomass (76%).  Ground beetles of the Wijster data set also showed a negative biomass trend, although at a less strong rate (mean = 2% per year). Over a period of 27 years, this would amount to 42% reduction in total biomass. Additionally, after 1995, the average rate of decline in biomass was more severe (4.1%), which, over a period of 27 years, would amount to 67%. | Macro-moths, beetles, and caddisflies declined by 3.8, 5.0, and 9.2% in mean number of individuals, respectively from 1997-2017 in the Netherlands. Whereas true bugs were stable and mayflies had uncertainty surrounding their trend (Hallmann et al., 2020).  Extrapolating over 27 years, macro-moths and ground beetles declined in biomass by 61 and 42%, respectively (Hallmann et al., 2020).  Divergent patterns were found between abundance and biomass measures. For abundance, abundant ground beetles had steeper declines than rare ones. Contrastingly for biomass, rare species fared worse (Hallmann et al., 2020). These results demonstrate that a decline in biomass cannot be directly assumed as a corresponding decline in abundance.  There is a bias towards monitoring butterflies, dragonflies, bees, and moths, which limits the extent to which we can draw conclusions for the state of insects as a whole (Hallmann et al., 2020).  Identifying causes of decline was beyond the scope of the study. |
| (Lister and Garcia, 2018) | 14/4/22 | **Climate-driven declines in arthropod abundance restructure a rainforest food web**  **Abstract**  A number of studies indicate that tropical arthropods should be particularly vulnerable to climate warming.  Although arthropods comprise over two-thirds of terrestrial species, information on their abundance and extinction rates in tropical habitats is severely limited.  Here we analyze data on arthropod and insectivore abundances taken between 1976 and 2012 at two mid-elevation habitats in Puerto Rico’s Luquillo rainforest. During this time, mean maximum temperatures have risen by 2.0 °C.  We discovered that the dry weight biomass of arthropods captured in sweep samples had declined 4 to 8 times, and 30 to 60 times in sticky traps.  Revealed sustained declines in abundance over two decades, as well as negative regressions of abundance on mean maximum temperatures.  Climate warming is the major driver of reductions in arthropod abundance, indirectly precipitating a bottom-up trophic cascade and consequent collapse of the forest food web   * Evidence? – average ambient temp is signif predictor in abundance   **Intro**  Given their abundance, diversity, and central roles as herbivores, pollinators, predators, and prey, the response of arthropods to climate change is of particular concern.  Deutsch et al. (5) predicted that, for insects living at mid-to-high latitudes, rates of increase should grow as climate warms, while in the tropics insects should decline by as much as 20%.  Although arthropods comprise more than two-thirds of all terrestrial species and are centrally important to the ecological well-being of the Earth’s ecosystems, long-term data on population abundance and extinction rates are severely limited (9).  **Results**  As several authors have pointed out, increased exposure to extreme temperatures may have a greater impact on fitness than gradual increases in average temperatures (6, 19, 20). At El Verde the proportion of maximum daily temperatures equal to or exceeding 29.0 °C increased significantly between 1978 and 2015.  Declines in biomass occurred across all 10 of the major taxa captured in the sweep samples.  Sticky-trap samples for the ground (Fig. 4A) and canopy (Fig. 4B) were indicative of a collapse in forest arthropods. The catch rate for the ground traps fell 36 times, from 473 mg per trap per day in July 1976 to 13 mg per trap per day in July 2012, and approximately 60 times, from 470 mg per trap per day to 8 mg per trap per day, between January 1977 and January 2013.  Analysis of Schowalter’s (23) canopy data also revealed significant decreases in invertebrate abundance scaled to foliage weight sampled between 1990 and 2010 (Fig. 5A), and a significant, nonlinear decline with increasing temperature.  **Discussion**  long-term declines have occurred in parallel with rising temperatures. Average ambient temperature is also a significant predictor of changes in the abundance of canopy invertebrates and walking sticks.  Research on causal factors has focused on anthropogenic disturbance and pesticides (57, 58). Given its long-term protected status (59), significant human perturbations have been virtually non-existent within the Luquillo forest since the 1930s, and thus are an unlikely source of invertebrate declines.  While we have focused on population collapse driven by climate change, shifts in altitudinal distributions of arthropods, insectivores, producers, and top predators may also play an important role in the observed declines in abundance.  An alternative to the climate-warming hypothesis for population declines in Luquillo and other tropical montane habitats is a mechanism proposed by Lawton et al. (126). In theory, clear cutting of lowland forests raises surface temperature, which in turn increases conductive heat flux from exposed ground to the atmosphere. This reduces both evapotranspiration and evaporative cooling (126) and lowers humidity.   * So warming is caused by land use change?   With regard to the Luquillo rain forest, the assumptions of the Lawton hypothesis simply do not hold, given a major regeneration of the lowland forest since the 1950s after a transition from an agrarian to a manufacturing economy (127). Consequently, the degree of shade, cooling, and humidification of the habitats surrounding the Luquillo Mountains have all increased (128). | Our knowledge of insect population trends in the tropics is severely limited (Lister and Garcia, 2018).  (Lister and Garcia, 2018) report sustained biomass declines across all 10 major taxa in a Puerto Rican rainforest between 1976 and 2012. As average ambient temperature was found as a significant predictor of abundance, the authors believe it is climate warming causing these declines. The authors disregard theories that the warming is caused by land-use change — for example, clearing of the rainforest increasing surface temperature — because the rainforest has not undergone significant human disturbance during the study period. Further, the authors also note that range shifts could play a role, though this was not investigated. |
| (Seibold et al., 2019) | 14/4/22 | **Arthropod decline in grasslands and forests is associated with landscape-level drivers**  **Abstract**  Recent reports of local extinctions of arthropod species1 , and of massive declines in arthropod biomass2 , point to land-use intensification as a major driver of decreasing biodiversity.  There are no multisite time series of arthropod occurrences across gradients of land-use intensity with which to confirm causal relationships.  It remains unclear which land-use types and arthropod groups are affected, and whether the observed declines in biomass and diversity are linked to one another.  Here we analyse data from more than 1 million individual arthropods (about 2,700 species), from standardized inventories taken between 2008 and 2017 at 150 grassland and 140 forest sites in 3 regions of Germany.  Overall gamma diversity in grasslands and forests decreased over time, indicating loss of species across sites and regions. In annually sampled grasslands, biomass, abundance and number of species declined by 67%, 78% and 34%, respectively. The decline was consistent across trophic levels and mainly affected rare species; its magnitude was independent of local land-use intensity. However, sites embedded in landscapes with a higher cover of agricultural land showed a stronger temporal decline.  However, sites embedded in landscapes with a higher cover of agricultural land showed a stronger temporal decline. In 30 forest sites with annual inventories, biomass and species number—but not abundance—decreased by 41% and 36%, respectively. This was supported by analyses of all forest sites sampled in three-year intervals. The decline affected rare and abundant species, and trends differed across trophic levels.  **Main body**  Time-series data relating to arthropods are limited, and studies have so far focused on a small range of taxa11,13,14, a few types of land use and habitat12—or even on single sites1,17.  It therefore remains unclear whether reported declines in arthropods are a general phenomenon that is driven by similar mechanisms across land-use types, taxa and functional groups.  Local arthropod populations can be affected by land use in the surrounding landscape; for example, through the drift and transport of pesticides and nitrogen by air or water23,24, through the effects of habitat loss on meta-communities (source–sink dynamics25) or by hampering dispersal.  Used data from the ‘Biodiversity Exploratories’ research programme.  Both the grassland and the forest sites cover gradients in local land-use intensity. Land-use intensity was quantified in the form of compound indices that are based on grazing, mowing and fertilization intensity in grasslands26, and on recent biomass removal, the proportion of non-natural tree species and deadwood origin in forests27.  We modelled temporal trends in arthropod biomass (estimated from body size; Methods), abundance and the number of species separately for grasslands and forests, and tested for the effects of local and landscape-scale land-use intensity on these trends, accounting for weather conditions. Analyses were conducted for all species together, and for different dispersal and trophic guilds.  The total number of arthropod species across all sites (gamma diversity) was substantially lower in later than in earlier years in both forests and grasslands (Fig. 1). Gamma diversity, biomass, abundance and number of species fluctuated over time but revealed an overall decrease with strongest declines from 2008 to 2010, especially in grasslands (Fig. 1).  In grasslands, both abundant and less abundant species declined in abundance (Fig. 2), but loss in the number of species occurred mostly among less-frequent species.  In forests, species that were initially less abundant decreased in abundance, whereas some of the most abundant species—including invasive species and potential pest species—increased in abundance.  This suggests that major drivers of arthropod decline in grasslands are associated with agricultural land use at the landscape scale.  This suggests that the drivers behind arthropod declines in forests also act at landscape-level spatial scales. | Based on more than a million arthropod records, Seibold et al (2019) generally observed decreases in Germany grassland and forest sites from 2008 to 2017. Biomass, abundance, and number of species declined by 67%, 78% and 34%, respectively in grasslands. In forests, biomass and species number—but not abundance—decreased by 41% and 36%, respectively. These number demonstrate the big difference in results observed based on the metric used.  There appears to be differences in how rare and abundant species react depending on habitat type. In grasslands, declines were mainly observed in rare species, whereas in forests, both rare and abundant species were affected (Seibold et al., 2019).  The use for land around more natural sites may influence the rate of decline. For example, in Seibold et al (2019), the researcher found that grassland sites surrounded by land with a higher proportion of agricultural land shower stronger declines. This could be due to dispersal ability of species being reduced in a fragmented habitat or effects of pesticide pollution. |
| (Habel et al., 2019) | 14/4/22 | Review paper - **Mitigating the precipitous decline of terrestrial European insects: Requirements for a new strategy**  **Abstract**  Agricultural intensification is the main driver of recent terrestrial insect decline, through habitat loss, reduced functional connectivity, overly intense management, nitrogen influx, and use of other fertilisers, as well as application of harmful pesticides. However, there are also supplementary and adversely synergistic factors especially climate change, increasingly intense urbanisation, and associated increase in traffic volume, artificial lighting and environmental pollution.  **Intro**  Although these studies have temporal and spatial restrictions, they have the same conclusions: (1) reduction of insect species richness, (2) shift in species assemblages, with reduced species evenness, and (3) decline in many species’ abundance, i.e. losses of biomass.  We focus here specifically on above-ground terrestrial insects, rather than aquatic insects, which face different (e.g. alien fish predation, channelization, damming of rivers, functionally significant reduced leaf litter), but sometimes overlapping (e.g. pesticide impact, increased nitrogen and fertilizer input, fragmentation of habitats) threats and stressors. In turn, soil insects are subject to some different (e.g. loss of leaf litter, soil erosion, changes in soil fungi composition) and some similar (e.g. changing microhabitats, landscape fragmentation, impact of invasive alien vegetation) impacts. All three realms, terrestrial, freshwater and soil, are affected by the pervasive effect of climate change, directly, or indirectly through changes in interaction networks.  An underlying assumption is that the drivers act as filters allowing certain species to survive or remain in high abundance, and others not.  Consequently, more rapidly developing and mobile taxa are less affected than others.  Habitat loss, isolation, and decreasing quality   * This results in reduction of individuals, and hence gene flow, between habitat patches. As a consequence, metapopulation structures (cf. Hanski 1999) are altered * Such species, not adapted for survival in small isolated populations by their genetic composition, often suffer from inbreeding, and can become extinct for that reason * Nitrogen accumulation and other fertilisers affect habitat quality, particularly in nitrogen limited ecosystems (such as semi-natural grasslands, bogs, and heathlands) through displacement of plants that are outcompeted by species benefitting from increased nitrogen availability. In particular, flowering herbs are replaced by grasses * Insecticides act directly as mortal agents, while herbicides reduce host plant availability and negatively impact insect population size * Aerially applied insecticides often drift, having an impact often far beyond where they were sprayed. * Protected areas are just a small fraction of the landscape, and they are not always effective in protecting insect species.   Climate change   * Higher temperatures are resulting in higher individual growth rates, and in poleward geographical range shifts * Increasing frequencies of extreme weather events (e.g. droughts, heavy rainfalls, extremely high but also low temperatures and rapid temperature changes) taking place in the wake of climate change also have additional negative effects on local populations of many species * The differential variation among drivers is inevitably interactive with the various traits among species. For example, species depending on particular resources (e.g. specific food plants for larval development or specific microhabitats) are greatly affected by deteriorating habitat quality. In contrast, sedentary species suffer more severely under the driver of increasing habitat isolation (Habel et al. 2016). * In short, any one driver at one time depends on the specific driver at a particular time. * As it is only the most generalist and widely-adapted species that can survive all the impacts at the same time, and the whole complex of drivers can interact in an adversely synergistic way, these two facets (traits vs. drivers contemporaneously)  inevitably are likely to exacerbate the decline in insect diversity  in a rapidly changing world.   Use of large data sets and sophisticated statistical analyses can then allow us to disentangle natural from anthropogenic drivers, as well as subsequent discrimination between the different anthropogenic divers.  Pollination in general has high economic value, with significant impact on crop yields, and so plays a pivotal role in agro-economy. Its annual value for agricultural plants is estimated to be 200–600 billion US$ (Klein et al. 2007).  We must also consider different aspects of crop management practices, such as crop rotation, intercrop combinations, composting, crop variety, biological control, and reliance on natural pollinators, among others. Instigating a suite of these management practices would close the yield gap between organic and conventional systems, especially when tailored to local conditions (Cunningham et  al. 2013). | Habel et al. (2019) believe agricultural intensification to be the main cause of insect decline, though climate change could be magnifying the effects. They also highlight the that the effects of drivers vary depending on time and space.  There will be a high price to pay if declines continue, for example pollination has huge impacts on crop yields, and hence has high economic value (Habel et al., 2019).  Future work should focus on determining the full effects of drivers, which is increasingly possible using large data sets and modern analysis tools (Habel et al., 2019). |
| (Dirzo et al., 2014) | 19/4/22 | **Defaunation in the Anthropocene**  Similar to other mass extinction events, the effects of this “sixth extinction wave” extend across taxonomic groups, but they are also selective, with some taxonomic groups and regions being particularly affected (2).  Loss of invertebrate biodiversity has received much less attention, and data are extremely limited. However, data suggest that the rates of decline in numbers, species extinction, and range contraction among terrestrial invertebrates are at least as severe as among vertebrates (23, 24).  Although less than 1% of the 1.4 million described invertebrate species have been assessed for threat by the IUCN, of those assessed, ~40% are considered threatened (17, 23, 24).  For the invertebrates for which trends have been evaluated in Europe, there is a much higher proportion of species with numbers decreasing rather than increasing (23).  We now recognize that extinction risk is often a synergistic function of both intrinsic species traits and the nature of threat (32, 34–37). For example, large body size is more important for predicting risk in island birds than mainland birds.  Land-use change is making it difficult for animals to expand their distributions into areas made suitable by climate change (25, 48).  The diversity of invertebrate communities, particularly their functional diversity, can have dramatic impacts on decomposition rates and nutrient cycling (59–61).  Improved monitoring and study of such taxa, particularly invertebrates, will be critical to advance our understanding of defaunation. | We may be experiencing the sixth mass extinction in evolutionary history, though it is hard to determine how hard insects are being hit due to limited data. Only around 1% of insect species have been assessed by the IUCN red list (Dirzo et al., 2014).  The risk of extinction is usually determined by a combination of nature of the threat and species attributes (Dirzo et al., 2014). |
| (Gillespie et al., 2020) | 19/4/22 | **Status and trends of terrestrial arthropod abundance and diversity in the North Atlantic region of the Arctic.**  **Abstract**  We begin this process by collating available data for a relatively well-studied region in the Arctic, the North Atlantic region, summarising the diversity of key terrestrial arthropod FECs, and compiling trends for some representative species.  **Intro**  The five FECs selected for terrestrial arthropods (blood-feeding, pollinators, decomposers, herbivores and prey for vertebrates).  Where long-term ([ 10 years) time series data were available for FECs or groups of species within FECs, we analysed trends over time using simple linear regression after checking for temporal autocorrelation in the R programming environment.  **General biodiversity patterns**  The diversity of arthropods decreases with increasing latitude (Fig. 1), supporting patterns shown in previous work.  **Status and trends of terrestrial arthropod FECs in the North Atlantic region**  Blood-feeding insects:   * mosquitoes, black flies and lice * Distributional and long-term trend information is limited for this group in much of the study region   Pollinators:   * The majority of arthropod species in this FEC also occur in other FECs (Fig. 2), demonstrating their extensive links throughout Arctic food webs. * The most promising long-term datasets for this FEC come from the arthropod samples collected at Zackenberg since 1996. Significant declines were detected in 7 of the 14 muscid (fly) species found in five or more years between 1996 and 2014 (Fig. 3), and dramatic ([80%) decreases in diversity and abundance have been reported in some habitats (Loboda et al. 2018). The differences in trends between species of muscid flies may relate to ecological differences among species, but classifying each species according to their body size and whether they are frequent flower visitors or not did not yield consistent patterns of abundance variation (Fig. 3).   Decomposers:   * represents the most common feeding mode in Arctic and global food webs   Herbivores:   * There are no long-term datasets that include all species in this FEC, but some groups are well represented. * For example, in Iceland, moth monitoring was established in 1995 as part of the Nordic Moth Monitoring Scheme. Preliminary data from the six longest running trap sites show significant positive trends in species richness at two locations, but negative or non-significant trends in abundance (Fig. 5).   Prey for vertebrates:   * Using the best long-term data currently available from the North Atlantic region, we took a first look at how this FEC might be changing over the last 20 years. We designated arthropod families from Zackenberg as potential members of this FEC group. Assessed trends in their total summertime abundance * Between 1996 and 2016, there were significant declines in the total abundance of potential vertebrate prey (p\ 0.001; Fig. 6, Table S11 in Supplementary Material) across all habitat types (i.e., heath and fen), with the strongest declines in the drier heath sites   We have been unable to report on the vast majority of FEC attributes and parameters for much of the Arctic and, where evidence is available, the signals in the data are subject to high levels of spatial and temporal variability.  Nevertheless, some of the simultaneous declining trends reported here support evidence of large decreases in arthropod biomass in other regions of the world. | In the Arctic where data spanning more than 10 years was available, Gillespie et al. (2020) found significant declines in 7 of the 14 species of muscid fly studied between 1996 and 2014. The researchers were unable to report on the majority of taxa due to insufficient data. |
| (Homburg et al., 2019) | 19/4/22 | **Where have all the beetles gone? Long-term study reveals carabid species decline in a nature reserve in Northern Germany**  **Abstract**  Long-term studies of insect diversity trends are still rare.  To gain insights into carabid diversity trends of ancient and sustainably managed woodlands, we analysed data of carabid beetles from a trapping study that has been run for 24 years in an old nature reserve of Northern Germany, the Luneburg Heath. We examined temporal changes in several diversity measures (e.g. biomass, species richness, functional diversity and phylogenetic diversity) and tested diverse species traits as predictor variables for species occurrence.  In contrast to recently published long-term studies of insect diversity, we did not observe a decline in biomass, but in species richness and phylogenetic diversity in carabids at our study site.  We assume the detected trends to be the result of external effects such as climate change and the application of pesticides in the surrounding.  **Intro**  Currently, long-term data on species’ occurrences revealing insights into insect diversity and abundance trends are rare (see for exception: Brooks et al., 2012; Hallmann et al., 2018)  Insects are the most diverse taxon on Earth in terms of species numbers, with beetles representing the largest proportion of this group of organisms.  Identifying the characteristics which are common in those species which decline may enhance our understanding of the drivers of species loss.  We specifically address the following research questions: (i) Have diversity, abundance, and biomass of forest carabids changed over the last 24 years? (ii) If there are changes, which traits are characteristic for the increasing or decreasing species?  As the few existing studies do not show coherent patterns and moreover use different measures of biodiversity (e.g. biomass, abundance or species numbers), it is difficult to derive reliable conservation strategies for ground beetles in woodland habitats.  **Methods**  Carabids from each trap were identified to species level and the number of individuals per species per trapping period counted.  We calculated the species richness using a rarefaction approach based on the minimum number of individuals trapped in a year (425 in the year 2004). Species richness was calculated using the package ‘vegan’.  For calculating functional diversity, we compiled traits typically used for ground beetles. Functional diversity was calculated after Petchey and Gaston (2002, 2006) using the ‘Gower’ distance metric for building the cluster dendrogram  We calculated the phylogenetic diversity for each year by calculation Rao’s quadratic entropy.  Species biomass was calculated from mean body length after Booij et al. (1994) and multiplied by the number of individuals per year. The total biomass per year over all species was then calculated.   * + - Is this accurate enough?   We tested for possible temporal linear changes in species numbers, species richness, phylogenetic and functional diversity as well as numbers of individuals and biomass using general linear models with ‘Year’ as the only explanatory variable. Model assumptions were checked graphically using diagnostic plots.  To test whether trait variables explained changes over time in the species occurrence (presence/absence), generalised linear mixed effects models (GLMMs) with binomial errors and ‘Species’ as random term was used. Analysing the interaction between ‘Year’ and each of the following trait variables ‘Body size’, ‘Food preference’ and ‘Hibernation type’ allowed us to assess a possible change across time in the relative occurrence of species with a respective trait level.  **Results**  Both the number of species and the species richness (Fig. 1a) declined significantly across years, and there was a trend for a reduction in functional diversity. In addition, the phylogenetic diversity decreased significantly over time.  In contrast, there was no significant change in the total number of individuals (across all species) caught over the years.  Likewise, the total biomass did not vary systematically over time (Table 3, Fig. 1c).  The likelihood of a species being present declined differently depending on its body size (GLMM, ‘Body size : Year’, v² = 10.26, d.f. = 1, P = 0.001; Fig. 2a): the smaller the species, the more pronounced was its decline.  **Discussion**  However, it is difficult to infer that long-term insect decline appears as a uniform global trend over all regions, habitats and taxa, as the referred British study on carabid species concluded a positive population trend of carabids in woodland and hedges (Brooks et al., 2012).  The exact influence of pesticide applications in surrounding areas can only be assumed, since we are lacking data on precise insecticide usage near the nature reserve and measures of chemical influences on the study plot.  In our study, diversity loss is represented by a decreasing number of small species, whereas the occurrence probability of large species was stable over time. This may be due to the fact that woodland specialists, at least in our study, were significantly larger than species specialised to other habitats and eurytopic species. This may also explain that we did not find a decline in biomass over time as only the smaller species showed a decrease.  Our recent results cannot disentangle which factor – global climate change or local pesticide application or both factors – is responsible for the observed species diversity trends.  This is of crucial importance when it comes to further enhancing the knowledge whether or not a global trend of an insect decline applies to all species and habitats. | (Homburg et al., 2019) did not observe a decline in abundance or biomass, but in species richness, functional diversity and phylogenetic diversity of carabids in Germany over 24 years.  Homburg et al. (2019) observed smaller species to have stronger declines. This could explain why an overall decline in species richness, but not biomass, was observed.  Researchers often speculate reasons for decline rather than empirically investigating the drivers. For example, Homburg et al. (2019) assume climate change and pollution to cause the observed declines, but do not include this in their study design. They do, however, investigate which species traits influence trends, concluding smaller body size to be particularly important.  Insects are most diverse taxon on Earth in terms in species numbers (see ICUN stats table). |
| (Brooks et al., 2012) | 19/4/22 | Large carabid beetle declines in a United Kingdom monitoring network increases evidence for a widespread loss in insect biodiversity  **Abstract**  We describe the first long-term, wide-scale and quantitative assessment of temporal changes in UK carabid communities.  Multivariate and mixed models were used to assess temporal trends over a 15-year period, across eleven sites in the UK Environmental Change Network.  We found substantial overall declines in carabid biodiversity. Three-quarters of the species studied declined, half of which were estimated to be undergoing population reductions of > 30%, when averaged over 10-year periods.  Overall trends masked differences between regions and habitats. Carabid population declines (10-year trend, averaged across species) were estimated to be 52% in montane sites, 31% in northern moorland sites and 28% in western pasture sites (with at least 80% of species declining in each case). Conversely, populations in our southern downland site had 10- year increases of 48% on average. Overall, biodiversity was maintained in upland pasture, and populations were mostly stable in woodland and hedgerow sites.  **Intro**  Studying species in isolation is unlikely to deliver a holistic understanding of the mechanisms driving their populations because their responses are linked to networks of interacting taxa (Magurran et al. 2010).  Models that assess geographical variation in the trends of multiple species and their interactions with habitats are therefore urgently required to bridge gaps in our understanding of biodiversity declines (Magurran & McGill 2010).  The lack of consistently collected and quantitative data in these studies has hampered accurate modelling of population trends.  **Methods**  Here, we analyse data within a 15-year time series between 1994 and 2008 for all sites, except Snowdon and Cairngorms that were considered separately because their trapping commenced in 1999.  Species population trends were estimated using linear mixed models fitted using residual maximum likelihood.  **Results**  We found an alarming overall decline in the biodiversity of carabid beetles amongst our network of study sites. Confirming the negative effect of time on most species. This supports our first hypothesis that there is a directional change in carabid community composition over time and demonstrates that this change results in a loss in biodiversity.  There were also significant reductions in total carabid counts (Fig. 2a), but more worryingly, population models revealed that around three-quarters of species had declined, half of which underwent significant reductions in their abundance, at rates estimated to exceed 30% when averaged over 10-year periods.  Significant interactions between the region by habitat trends for total carabid counts, with median 10-year trends varying from 48.4% declines in our northern moorland and western pasture sites, to 50% increases in our southern downland site.  Populations were much more stable in woodland and southern hedgerow transects, where only one-fifth of species underwent significant changes, and the median 10-year change was a 6.2% increase.  Although such taxa were usually stable in woodland and southern hedgerow transects, they were often declining elsewhere.  **Discussion**  Given that the trends in carabid biodiversity are mostly downward, it would be tempting to ascribe one dominant driver of change. However, responses varied significantly between regions and habitats, suggesting more complex interactions between local population drivers and wider-scale factors.  Woodland and hedgerows also have particularly stable microclimates (Geiger 1957), which may buffer wider-scale perturbations and explain why their carabid communities were stable in this study.  Carabid declines are often more pronounced when species are adapted to either very dry or wet conditions. | Three-quarters of UK carabids declined in Brooks et al. (2012) between 1994 and 2008, though there were marked difference between habitat types. Trends varied from 50% declines in northern moorland and western pasture, to 50% increases in southern downland. Furthermore, certain taxa were found to be stable in certain habitats, whilst declining elsewhere.  Brooks et al. (2012) highlight the debate over whether we should be studying species-level trends or gathering a more holistic opinion. |
| (Fox et al., 2019) | 19/4/22 | **Insect population trends and the IUCN Red List process**  **Abstract**  Temporal population trends can provide important evidence for such assessments, but imperfect sampling (observation errors) and short-term stochastic variation in population levels caused by environmental variability (process errors) can reduce the reliability of trends and lead to incorrect quantification of extinction risk. The assessment of insect taxa is likely to be particularly prone to these problems, due to the highly dynamic nature of many insect populations, driven by short life-cycles and sensitivity to environmental factors such as the weather.  54 butterfly and 431 macro-moth species - For both taxa, varying the start year of the 10-year population trend had a substantial effect on whether particular species met Red List thresholds and on the overall number of species assessed as threatened.  **Intro**  Inaccurate detection of underlying species population trends can result in incorrect Red List classification.  These studies are based almost exclusively on vertebrate examples, where biological traits (e.g. generation times, population growth rates) and specific environmental drivers (e.g. human exploitation) may differ markedly from those of insects.  10-year population trends of insects may not be sufficiently reliable to enable the accurate classification of extinction risk in the Red List process, but rather reflect spurious responses to short-term environmental stochasticity. Thus, Red List classifications based on such trends are likely to be strongly affected by the start date of the 10-year trend.  **Discussion**  An obvious solution to the problem is to measure population trends over a longer period of time rather than the last 10 years. Linear trends over the 40+year time series available for both UK butterflies and moths dampen the effects of annual variation, providing a more robust assessment. | Insect populations prove particularly hard to monitor due to their highly dynamic nature. High variation between years is very common, hence the need for long-term data sets to reduce the effects of yearly variation (Fox et al., 2019).  When assessing whether insect species met the threshold to be classified as threatened, varying the start year of trends in butterfly and moth species influence the number of species classified as such (Fox et al., 2019). |
| (Didham et al., 2020) | 19/4/22 | **Interpreting insect declines: seven challenges and a way forward**  **Abstract**  Insect population fluctuations are complex. Greater care is needed when evaluating evidence for population trends and in identifying drivers of those trends.  **Intro**  For the vanishingly small proportion of these in which conservation risk has been evaluated (e.g. Langor, 2019), the status and trends are at least as sobering as they are for vertebrate species (Dirzo et al., 2014; Forister et al., 2019).  In the rush to address ‘global insect declines’, it has never been more important to pause and think critically about what constitutes evidence for decline in the first place. For most insects, high inter-annual variability is the norm rather than the exception (e.g. Redfearn & Pimm, 1988; Roubik, 2001), but it poses serious problems in determining what the baseline reference state should be for historical abundance, and inherently increases the length of time series required to separate signal from noise (White, 2019).  **The false baseline effect**  One logical precondition for estimating rates of long-term population decline is to have a sound quantitative estimate of historical population abundance. Frustratingly, such estimates are rarely available, as the vast majority of ‘decline’ studies only begin after numbers were perceived to be changing.  Shifting baseline phenomenon.  **The detection bias effect**  All the arguments presented so far have assumed that variation in sample abundance is an accurate representation of variation in local population abundance. Unfortunately, few studies can achieve a complete census of all individuals in a population, so it is a practical necessity in insect monitoring that standardised sampling methods are used instead.  Light trapping is used as a standard method for sampling moths, but in many rapidly urbanising areas, the number of competing anthropogenic sources of light has been increasing dramatically through time (Gaston et al., 2015; Owens et al., 2020). Thus, moth captures might decline through time simply because individuals are attracted elsewhere and are not as detectable in the monitoring traps.  **The popcorn effect**  The degree of covariance between local and regional estimates of population change is typically unknown.  There is a tendency to take a few kernels of local data and expand these into a superficially inflated shell of population response as a whole.  **The way forward**  Subjectively, the examples presented above suggest to us that most biases will lead to over-estimates of reported rates of insect decline. The exception (in our subjective opinion, once again) could be the shifting baseline effect, in that current population trend estimates might underestimate the magnitude and rate of losses that would have been inferred if we had older and more reliable historical baseline estimates. | Shifting baseline phenomenon may be influencing our opinions on insect trends. It is hard to find solid evidence to counter this due to a lack of historical records of insect trends (Didham et al., 2020).  High variation from year to year also affects the usefulness of short-term studies (Didham et al., 2020).  Detection bias – nearly impossible to monitor complete census of all individuals in a population. |
| (Montgomery et al., 2020) | 20/4/22 | **Is the insect apocalypse upon us? How to find out**  **Abstract**  Recent reports are sufficiently robust to justify immediate actions to protect insect biodiversity worldwide. We caution, however, that we do not yet have the data to assess large-scale spatial patterns in the severity of insect trends.  Most documented collapses are from geographically restricted studies and, alone, do not allow us to draw conclusions about insect declines on continental or global scales, especially with regards to future projections of total insect biomass, abundance, and extinction.  Only a small fraction of insect species have had any substantial population monitoring, millions of species remain unstudied, and most of the long-term population data for insects come from human-dominated landscapes in western and northern Europe.  **Intro**  We need to understand how quickly populations are trending upward or downward.  Are the rates of population change of insects roughly on par with those of plants, birds, and mammals?  If insects are declining at rates appreciably faster than vertebrates and plants in the same regions, it may be prudent to focus research on stressors that especially impact insects.  Finally, with so few data from outside Europe, it is difficult to gauge how widespread the phenomenon is, especially in the tropics (Basset and Lamarre, 2019; Janzen and Hallwachs, 2019) and southern temperate regions, where more than 85% of all insect species occur (Stork, 2018).  **Challenges**  We lack robust records of past insect populations and diversity.  The geographic distribution of haphazardly distributed baseline data is also a problem – those data that do exist come mostly from “anthroposcapes,” or human-altered ecosystems.  Additionally, large natural fluctuations in invertebrate populations from year to year, and sometimes even within a single year, make drawing conclusions from demographic studies of insects challenging.  Entomologists and those reliant on sound insect identifications also face an enormous taxonomic impediment (Samways, 1993; Habel et al., 2019), especially in tropical regions. It is difficult to know what we are losing when 80% of insect species (representing, conservatively, four million species) remain undescribed and their natural histories unknown (Stork, 2018).  High insect species diversity compounds this problem; identification of every insect even in a small sample in an area with low alpha diversity can be time- or cost-prohibitive.  **Research recommendations**  First, we need to establish insect monitoring networks on a global scale. By using repeatable sampling methods, new monitoring programs can augment pre-existing ones, and help determine population trends, identify drivers of trends, and serve to engage the public through community science.  Although biomass is an imperfect estimator of diversity because it can be sensitive to changes in abundances of large species (e.g., Shortall et al., 2009), it is a valuable metric from the ecosystem perspective. Determining biomass trends also does not require fine-scale taxonomic knowledge, which is often limited to individuals with specialized training.  Continuous, or at least multi-year, time-series are especially valuable for insects, where year-to-year population variation can be high.  Surveys across light pollution, agricultural intensification, pesticide use, plant invasion, urban heat island, human density, or other gradients could provide insight into what factors are contributing to insect declines and their relative importance.  To combat publication bias, researchers, reviewers, and journal editors alike need to publish reports of increasing and stable trends, in addition to documenting declines. Reports of where insects are not declining are as important as reports of where they are declining, since this heterogeneity can help elucidate key threats. Unbiased reporting will also reduce systematic biases in the literature, which is helpful for researchers performing systematic reviews and meta-analyses.  Long-term monitoring studies can be unappealing to funders and yet are the main lens through which we understand the rapid changes in biological systems. | We have enough evidence that we need to do more to mitigate insect declines but we do not yet fully understand the extent and reasons (Montgomery et al., 2020).  So far, the geographical restrictiveness of studies to human-dominated landscapes mainly in western and northern Europe as well as taxonomic restrictiveness makes it hard to generalise how the strength of trends on a global scale. This is worsened by insects displaying large variation in population size between years, as well as our lack of knowledge on the majority of species, many of which have not even been described (Montgomery et al., 2020).  Future papers should also report stable or positive trends, to ease publication bias and improve meta-analyses (Montgomery et al., 2020). |
| (Loboda et al., 2018) | 20/4/22 | **Declining diversity and abundance of High Arctic fly assemblages over two decades of rapid climate warming.**  **Abstract**  We quantified temporal assemblage turnover of Arctic Diptera (flies) in the Muscidae, one of the most diverse and abundant families of Arctic insects, using time series data from Zackenberg, north-east Greenland.  We measured temporal patterns of abundance, diversity, and composition of muscid assemblages in wet fen, mesic and arid heath habitats from yearly collections spanning 1996–2014 and tested their relationship to climate.  A total of 18 385 individuals representing 16 species of muscid flies were identified.  A significant decrease of 80% of total muscid abundance was observed during the study period.  Species richness declined in each habitat type but this trend was not significant across habitats.  The number of common and abundant species also decreased significantly over time across habitats revealing a temporal modification of species evenness.  Shift in composition in each habitat and decline in muscid abundance across habitats were associated with summer temperature, which has significantly increased over the study period. However, relationships between temperature and muscid abundance at the species level were noticeable for a few species only.  Habitat types may modulate insect species responses to recent climate change.  **Intro**  Species-specific responses to environmental change have led to contrasting responses at the community level, and ecological traits could influence how species will respond to climate change.  Using one of the longest time series data sets on Arctic insect biodiversity, the Greenland Ecosystem Monitoring programme initiated in 1996 at Zackenberg in north-east Greenland, we documented interannual patterns and long-term trends of abundance, diversity and composition of muscid fly assemblages at the species-level, in three habitats, between 1996 and 2014.  **Methods**  Analyses described below were conducted separately for habitat-specific ensembles and for the whole assemblage pooling all habitats (defined hereafter as ‘across habitats’).  We explored long-term trends in abundance for all species pooled and separately for dominant species (species making up at least 15% of the total abundance).  Diversity metrics were calculated using individual-based rarefaction and extrapolation curves for each year.  To explore patterns and shifts in community composition over time, the similarity of muscid assemblages across years was assessed with non-metric multidimensional scaling ordinations (NMDS).  Abundance residuals were then regressed against climate residuals to determine relationship between climate and total muscid abundance in each assemblage as well as species abundance of the dominant species in each assemblage  **Results**  16 species in 4 genera  Significant declines in muscid abundance were found across habitats (Fig. 3a), in the arid heath (Fig. 3b) and in the wet fen (Fig. 3d). The declines in abundance correspond to a loss of 80% of individuals between 1996 and 2014 across habitats, 85% in the wet fen and 71% in the arid heath.  Species richness (Hill number 0 D) significantly decreased over time within each habitat (Fig. 4b, c, d) but not across habitats.  According to the PERMANOVA, changes in composition similarity over time were significant across habitats (R20.37, p0.001, Fig. 5a) and in the wet fen (R20.42, p0.001, Fig. 5d), but not in the arid (R20.15, p0.06, Fig. 5b) or mesic heath (R20.11, p0.17, Fig. 5c).  Temporal changes in composition similarity were habitat-specific, but similarity between habitats did not change over time (F2,510.82; p0.45), indicating that there was no biotic homogenization across habitats of the muscid assemblage.  Summer temperature was significantly related to assemblage composition in the arid heath (R2 adj0.32, p0.02, Fig. 5b), in the mesic heath (R2 adj0.33, p0.02, Fig. 5c), and in the wet fen (R2 adj0.50, p0.01, Fig. 5d). Recent assemblages are associated to warmer temperatures. In the wet fen, spring temperature was also related to compositional change over time (R2 adj0.42, p0.01).  Variation in muscid fly abundance at Zackenberg was significantly related to temperature in a few cases, but not to timing of snowmelt (Table 1). Total muscid abundance decreased significantly as summer temperature increased across habitats and in the mesic heath. In the arid heath, total muscid abundance was negatively related to spring temperature. However, at the species level, most relationships between abundance variation and climate predictors were not significant (Table 1).  **Discussion**  Our results suggest that change in species composition was mainly attributable to significant decreases in species abundance, with a loss of 80% of muscid individuals across habitats documented between 1996 and 2014 at Zackenberg.  Ecosystem functions and services, especially pollination, may depend strongly on the abundance of common species and not necessarily on the number of species delivering the service.  The abundance of most species did not correlate with temperature but some of the most abundant taxa showed unique patterns; the abundance of D. segnis and S. sanctipauli both decreased with increasing summer temperatures but the trend was only detectable across habitats for D. segnis and in the mesic heath for S. sanctipauli. These results suggest that muscid species are not equally sensitive to temperature and that habitat characteristics might modify their temperature response. | 16 species of muscid flies were monitored by Loboda et al. (2018) in Greenland between 1996 and 2014. The researchers found a significant decrease of 80% of total abundance, which affect abundant species as well as rare ones. At species level, most climate predictors could not explain the trend.  For pollination services, the abundance of species, rather than species richness, may be more important in the continuation of this service (Loboda et al., 2018). |
| (Boyes et al., 2019) | 20/4/22 | **Bucking the trend: the diversity of Anthropocene ‘winners’ among British moths**  **Abstract**  Research to date has largely focused on declining species, while species that are becoming more common have received relatively little attention.  We examine changes in 51 successful species between 1968 and 2016 using 4.5 million occurrence records and a systematic monitoring dataset.  The responses of Anthropocene winners are heterogeneous, suggesting multiple drivers are responsible.  Changes in range and local abundance frequently occur intermittently through time, demonstrating the value of long‑term, continuous monitoring.  There is significant diversity among the winners themselves, which include widespread generalists, habitat specialists, and recent colonists.  **Intro**  The Rothamsted Insect Survey, a standardised network of light-traps, provides detailed information on abundance change for the most frequently caught species (Conrad et al. 2004). These data have revealed that two-thirds of GB’s commonest macro-moths have declined since 1968, while 84 of the 334 species examined showed statistically significant positive trends in abundance.  Trends in frequency of occurrence have been produced for 673 species (approximately 80% of GB macro-moths), using the National Moth Recording Scheme, a citizen science project that contains millions of biological records and can offer high-resolution insights into range change (Fox et al. 2011). Between 1970 and 2010, significant declines were detected in the frequency of occurrence (at the 10km x 10km grid square scale) for 260 species, whereas 160 others showed significant positive trends (Fox et al. 2014).  We ask whether these winners demonstrate shared pathways of success as they move through the multidimensional space of rarity/commonness?  **Methods**  Of the 330 macro-moths that had published trends for both abundance and occupancy, 48 species showed statistically significant increases in both measures.  **Results**  The majority (42/51) of the winners are broadly habitat generalists. Seven species have a strong habitat preference for broadleaved woodland, one is found predominantly in coniferous woodlands, and one favours damp habitats on acidic soils.  **Discussion**  GB represents only a small part of the global range of most of its moths. For most other countries in Europe (particularly southern Europe), there is insufficient data to assess changes in the prevalence of moths. Species may be faring badly in other parts of their global range; thus, the success of the winners documented here might be relatively localised.  There are also some examples of apparent trend reversal, which may imply success is a transient state; it may be that some of these species will only be winners for a relatively short period of ecological time.  Biodiversity trends are not universally negative.  The heterogeneity of the responses shown by winners suggests that multiple drivers may be involved (Table 1). These drivers are poorly understood.  The search for ecological traits associated with winners is an obvious topic for future investigation. | One example of a paper which focuses on increasing species is the reporting of increasing British moths by Boyes et al. (2019). Nevertheless, though the researchers focused on the 51 species that increased in abundance ad occupancy, it cannot be ignored that the remaining moths of the 330 that had sufficient data, declined. Further, these trends may prove transient — the trends could reverse over time. However, this paper does well at highlighting that not all species are in decline.  The majority of the increasing moth species were generalists (Boyes et al., 2019).  The traits that mean species survive may be as important to identify as those which lead species to decline (Boyes et al., 2019). |
| (van Strien et al., 2019) | 20/4/22 | **Over a century of data reveal more than 80% decline in butterflies in the Netherlands**  **Abstract**  We summarised the species trends in a Multi-Species Indicator (MSI) by taking the geometric mean of the species indices.  Between 1890–1930 and 1981–1990, the MSI decreased by 67%; downward trends were detected for 42 species, many of which have disappeared completely from the Netherlands. Monitoring count data available from 1992 showed a further 50% decline in MSI. Combined, this yields an estimated decline of 84% in 1890–2017.  We also assessed separate MSIs for three major butterfly habitat types in the Netherlands: grassland, woodland and heathland. Butterflies strongly declined in all three habitats alike. The trend has stabilised over recent decades in grassland and woodland, but the decline continues in heathland.  **Intro**  In order to assess restoration success adequately, we need to know how the state of biodiversity has changed, not only over recent years, but also over a long period. This requires data on historic species occurrences, but such knowledge is fragmentary.  A wealth of data from earlier periods also exists, but these data were not collected using standardised field protocols; they are ‘opportunistic’. We re-analyse historic opportunistic data to produce a quantitative estimate of the overall long-term change in butterfly occurrence in the Netherlands: the Multi-Species Indicator (MSI).  Occupancy modelling is currently viewed as the best statistical correction method available. It takes into account the detection probability of species and through that it enables to adjust for observer effort.  **Methods**  We added site as random effect, to account for spatial differences in surveys over time.  **Results**  From 1890 to 2017, the MSI based on 5 km × 5 km sites steeply declined (P < 0.05; Fig. 1). Butterflies overall decreased by 73% in the mean number of occupied 5 km × 5 km sites.  Considerable further decline from 1990 to 2017 (P < 0.05; Fig. 2). In this period, the distribution of 22 of 46 species for which we had sufficient data decreased, while that of 16 species increased (Table S3).  **Discussion**  Most of the older records are from specimens in museum and private collections, for which collectors tried to balance the number of specimens across species. As a consequence, specimens of the most common species have often been ignored if enough specimens had already been collected. So, the increase of some common species is probably over-estimated. | Van Strien et al. (2019) report an overall 84% decline in butterflies in the Netherlands between 1890 and 2017. Declines were strong in all of grassland, woodland, and heathland. This study relies on historical and opportunistic records, likely to underestimate the abundance of common species once enough specimens had been collected. This could result in the increase of common species being over-estimated. |
| (Wagner et al., 2021a) | 20/4/22 | **A window to the world of global insect declines: Moth biodiversity trends are complex and heterogeneous.**  **Abstract**  Rates of decline for dietary and ecological specialists are steeper than those for ecologically generalized taxa.  With the exception of recent reports from Costa Rica, the most severe examples of moth declines are from Northern Hemisphere regions of high human-population density and intensive agriculture.  **Intro**  To date, there have been only modest efforts to evaluate the spatial, temporal, and taxonomic aspects of insect declines, which has limited the capacity to identify the primary causal factors.  **Moth Biodiversity Changes Are Spatially and Taxonomically Heterogeneous**  Spatially, moth trends vary at continental, regional, and even local scales, which suggests that different stressors are in play. While patterns of moth decline are prevalent across western, central, and northern European countries (17, 21–24, 26), typically, there is considerable within-country heterogeneity.  Even in studies showing clear overall declines, some fraction of the moth fauna is increasing (e.g., refs. 17 and 21 and GB case study below). We are unaware of an instance where all lineages are in collapse, a signal that would implicate stressor(s) acting uniformly across families of Lepidoptera.  Temporal changes in metrics used to assess changes in biotic communities, such as species richness, biomass, and trends in abundance and occupancy, can differ for many reasons. These could be spurious, stemming from differences in measurement, scale, or time lags, or they could reflect real discrepancies driven by differential responses of individual species, with the identities of winners and losers being due to different traits, demographics, and spatial distributions, generating conflicting signals at the assemblage level (30).  **Stressors**  Drivers may interact additively, synergistically, or antagonistically and operate at different locations and over different time periods.  Land-use change includes many stressors known to affect biodiversity: deforestation, agricultural intensification, commercial forestry practices, and urbanization. In this broad sense, land-use change surely has the greatest impact on the status of moths in Europe (23, 31, 38, 39) and on insects and other wildlife globally.  **Common Traits Among Moth Taxa that Are Declining**  In two studies, body size (forewing length) was the single best predictor of declining populations (70, 71).  **Consequences to Food Webs and Ecosystem Function**  While adults are important as pollinators (7, 77), the best-resolved net-works focus on trophic interactions, with moths providing a large proportion of the consumer nodes connected to plants, as well as the prey or host nodes connected to predators and parasitoids.  **Concluding remarks**  Long-term datasets from western, central, and northern European countries confirm that moth decline is widespread across the continent, but demographic data from outside of Europe are sparse. While our data for caterpillar abundances in Arizona, Costa Rica, and Ecuador contribute to an understanding of population and community dynamics of Lepidoptera outside of Europe, there remains an urgent need for more data to make robust conclusions about the scope and nature of global insect declines. | There is high heterogeneity in insect population trends, which is highlighted for moths by Wagner et al. (2021a). Habitat and dietary specialists show stronger rates of decline than generalists. Although the overall pattern is decline, some proportion of species are increasing.  There is an urgent need for more data to untangle the geographical and temporal effects of drivers, and identify examples where there drivers interact (Wagner et al., 2021a). |
| (Saunders et al., 2020) | 20/4/22 | **Moving On from the Insect Apocalypse Narrative: Engaging with Evidence-Based Insect Conservation**  **Abstract**  Confusing and inaccurate science communication on this important issue could have counterproductive effects on public support for insect conservation. The insect apocalypse narrative is fuelled by a limited number of studies that are restricted geographically (predominantly the United Kingdom, Europe, the United States) and taxonomically (predominantly some bees, macrolepidoptera, and ground beetles).  **Intro**  In their peer-reviewed paper, Sánchez-Bayo and Wyckhuys (2019) extrapolated beyond the limitations of their review to suggest evidence of global decline across all insect taxa.  The insect apocalypse narrative spread unchecked via popular and social media platforms, and subsequent peer-reviewed articles have cited all of these studies uncritically as evidence of global-scale insect decline or ecosystem collapse.  **Limitations of the apocalypse narrative**  Most of these studies are from Europe and the United Kingdom (figure 1), and many are highly localized, collecting data from one specific location (e.g., one nature reserve) or from one region within a country. All of the studies showed increases or no changes for some of the focal taxa across the analyzed time period.  The relevance of different metrics to identifying overall global population trends was also largely overlooked or misrepresented in popular media coverage; for example, The Guardian coverage of the Hallmann and colleagues (2017) study claimed that insect abundance had fallen, but the study only measured biomass (Carrington 2017).  A more immediate solution is to invest in building knowledge of global insect diversity, insect species ecology and life histories, and the effect of human impacts and environmental change on taxonomic groups (box 1).  **Human impacts on insect communities.**  We still have very limited knowledge of how multiple drivers impact insects across the whole of their life cycle or of how these drivers affect community structure and functional diversity. | Saunders et al. (2020) believe we have a long way to go before we can fully speculate about the state of insect populations. They argue Sanchez-Bayo and Wyckhuys paper was damaging due to geographical extrapolation of findings beyond the scope of the study, but has which nevertheless become prominent in the media and subsequent papers as evidence of an ‘Insect apocalypse’. The research conducted so far has left major gaps in our understanding of the drivers of trends too. Further, many studies focus on declines when in fact, it is rare that a study does not report stable or positive findings for a certain proportion of taxa. |
| (Van Klink et al., 2020) | 20/4/22 | **Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances**  **Abstract**  We compiled data from 166 long-term surveys of insect assemblages across 1676 sites to investigate trends in insect abundances over time. 41 countries  Overall, we found considerable variation in trends even among adjacent sites but an average decline of terrestrial insect abundance by ~9% per decade and an increase of freshwater insect abundance by ~11% per decade.  Both patterns were largely driven by strong trends in North America and some European regions. We found some associations with potential drivers (e.g., land-use drivers), and trends in protected areas tended to be weaker.  **Main body**  Despite the attention from the media, policy-makers, and scientists, it remains unclear whether such declines are widespread across realms and among geographic regions.  We used the amassed data to evaluate changes in total insect abundance and biomass, as well as the geographic distribution of such changes.  Among these, 130 datasets reported only changes in insect abundances (i.e., number of individuals) in an assemblage, 13 datasets reported only the biomass of all insects in an assemblage, and 23 datasets reported both metrics. The data spanned from 1925 to 2018.  We analyzed the data using a hierarchical Bayesian model accounting for variation at the study, study area, and site level.  The mean trend estimates of insect abundance and biomass were similar (Fig. 2A) but differed in strength of evidence because of the lower data availability for biomass (table S2).  The positive trends in the fresh-water realm may partially counter the negative terrestrial trends, because a model combining both realms showed no evidence for a directional trend (Fig. 2A). However, because fresh water represents only 2.4% of the earth’s terrestrial surface (15, 16), such a combined model is likely to be a poor representation of trends in total insect numbers at any spatial scale.  We found that the trends in protected areas were weaker than those in unprotected areas (Fig. 4), although there was still a moderate negative trend in terrestrial protected areas. This difference suggests a possible association between insect trends and land-use change.  We calculated the relative change in temperature and precipitation over the sampling period at local and regional scales for each site (14) to test for a potential role of climate change, but found no evidence for any associations at either scale.  As with most data compilations of this kind, our data sources were not representatively spread across the world.  Protected areas were overrepresented in our dataset (34% of the sites) relative to the percentage of the terrestrial surface currently under protection (15%) (31). This means that locations where human land use is most intensive, and thus where the strongest effects on insect trends might be expected, were underrepresented.  We found an average increase in fresh-water insect abundances that might, at least partially, reflect improvements in water quality. This, in combination with our finding that trends were weaker in protected areas, suggests that appropriate habitat protection and restoration may be effective strategies for mitigating changes in insect assemblages.  Criticised by (Jähnig et al., 2021):   * First, total abundance and biomass alone are poor indicators of the status of freshwater insect assemblages, and the observed differences may well have been driven by the replacement of sensitive species with tolerant ones. * Second, many of the datasets poorly represent global trends and reflect responses to local conditions or non-random site selection | Van Klink et al. (2020) found an average 9% decline per decade of terrestrial insect abundance but an 11% increase in freshwater insects over 41 countries between 1925 and 2018. A combined model of both terrestrial and freshwater insects showed no clear trend, though the influence of freshwater species could be over-estimated due to freshwater only covering 2.4% of the Earth’s terrestrial surface.  Unprotected areas displayed stronger trends than protected areas. This implies Van Klink et al. (2020) may have missed areas where the strongest effects occur due to an overrepresentation of protected areas in the study.  Van Klink et al. (2020) found no association between climate change and insect population trends, either at local or regional scale.  Jähnig et al. (2021) criticise Van Klink et al. (2020) for disregarding that the differences in abundance and biomass do not take into account changes in community structure by the replacement of sensitive species with tolerant ones. Further, the non-randomly selected sites  cannot be used to report global trends. |
| (Wepprich et al., 2019) | 20/4/22 | **Butterfly abundance declines over 20 years (1996 to 2016) of systematic monitoring in Ohio, USA**  **Abstract**  We estimate the rate of change in total butterfly abundance and the population trends for 81 species using 21 years of systematic monitoring in Ohio, USA.  Total abundance is declining at 2% per year, resulting in a cumulative 33% reduction in butterfly abundance. Three times as many species have negative population trends compared to positive trends.  Even common and invasive species associated with human-dominated landscapes are declining, suggesting widespread environmental causes for these trends.  **Methods**  We accounted for differences in sampling across sites and years so that our modelled trends would capture changes in abundance rather than changes in detection probability.  We used generalized linear mixed models to estimate temporal trends in relative abundance for 81 species from their population indices.  Of the 81 species, we classified 14 as migratory species and 67 as year-round residents of Ohio. We collected traits that relate to insect responses to climate change and habitat change.  **Results**  The statewide relative abundance summed across all species declined at an annual rate of 2.0% (β1 = -0.020, std. err. 0.005, p < 0.001), accumulating a 33% decline over 1996–2016.  Positive and negative species trends are distributed across the phylogenetic tree.  The Monarch (Danaus plexippus) was the only migratory species in decline, although the others had erratic annual fluctuations that make trend estimation difficult.  Univoltine species had more negative population trends than bivoltine or multivoltine species. Overwintering stage did not have a strong effect on trend.  **Discussion**  Although few may share concern for the most widespread, invasive butterfly in the world’s agricultural and urban settings [72], declines in Pieris rapae could be indicative of persistent environmental stressors that would affect other species as well.  Even with systematic monitoring, accurate estimates of insect abundance are missing from many species—a fifth of regularly observed species in Ohio did not meet our minimum data requirements to for us to estimate trends.  Rather than recommending other systematic monitoring programs accumulate decades of data before assessing  insect declines, we would advocate sharing data across regional programs to increase statistical power, as in [11], and integrating systematic monitoring with historical records and opportunistic observations to assess insect vulnerability more rapidly by using all potential sources of data [82,83]. | For 81 species of butterfly in Ohio from 1996-2016, 3 times as many species had negative population trends compared to positive trends. Of the species which declines, common and invasive species were also affected. Univoltine species were more strongly negatively affected (Wepprich et al., 2019).  Even now, studies are suffering from a lack of data. For example, (Wepprich et al., 2019) could not report on a fifth of regularly observed butterflies in Ohio due to this. |
| (Outhwaite et al., 2022) | 20/4/22 | **Agriculture and climate change are reshaping insect biodiversity worldwide**  **Abstract**  Although research has shown that biodiversity changes are driven primarily by land-use change and increasingly by climate change6,7 , the potential for interaction between these drivers and insect biodiversity on the global scale remains unclear.  Here we show that the interaction between indices of historical climate warming and intensive agricultural land use is associated with reductions of almost 50% in the abundance and 27% in the number of species within insect assemblages relative to those in less-disturbed habitats with lower rates of historical climate warming.  These patterns are particularly evident in the tropical realm, whereas some positive responses of biodiversity to climate change occur in non-tropical regions in natural habitats.  A high availability of nearby natural habitat often mitigates reductions in insect abundance and richness associated with agricultural land use and substantial climate warming but only in low-intensity agricultural systems.  **Main body**  Little research has addressed the impact of drivers at the global scale.  Human land use and climate change have emerged as key determinants of changes in the biodiversity of well-studied species groups (insects and non-insects) and regions (such as the UK and Europe)2,6,14–16. Evidence suggests that these drivers may interact synergistically, leading to greater responses than would be expected had they acted independently17.  The impact of land-use–climate interaction is likely to vary spatially. In general, tropical species are considered to be more sensitive than temperate species to climate change24,25.  When warming does occur, those with narrower thermal niches are the most likely species to be pushed towards or beyond their thermal limits by regional climate change or by microclimatic changes caused by land-use change24. It is therefore likely that the effects of interaction between land use and climate change will be strongest in the tropics.  We analysed site-level comparisons of local insect biodiversity across land-use types from the Projecting Responses of Ecological Diversity in Changing Terrestrial Systems (PREDICTS) database31.  Although the data span 20 years (from 1992 to 2012), the individual studies within which the biodiversity comparisons were made were generally collected over a very short time span.  We conducted our analysis using mixed-effects models specified to explore three main hypotheses: (1) conversion to agriculture and intensification of agriculture reduces insect biodiversity; (2) insect biodiversity will be reduced the most where historical climate warming interacts with agricultural land use, particularly in higher-intensity agriculture and tropical regions; and (3) natural habitat in the surrounding landscape can mitigate the detrimental effects of agricultural land use and climate warming on insects.  Four major land-use and land-use-intensity classes of primary vegetation, secondary vegetation, low-intensity agriculture and high-intensity agriculture.  We show that in high-intensity agriculture, which is typically characterized by chemical input, low crop diversity, large field size, mechanization or high livestock density, the insect total abundance and species richness were reduced 45% and 33% compared with those in primary vegetation, whereas those in low-intensity agriculture were reduced 19% and 22%, respectively.  This loss of insect biodiversity in agricultural systems will probably reduce the provision of ecosystem services essential to agriculture such as pollination and pest control35,36. Moreover, theory suggests that declines in biodiversity could reduce the resilience of natural and agricultural ecosystems to future shocks such as those from extreme climatic events11,37.  Warming equivalent to 1 s.d. of baseline temperature variation (standardized temperature anomaly of 1.0) led to 49% and 27% reductions in insect abundance and species richness in intensive agriculture, respectively, compared with those in primary vegetation with no climate warming (Fig. 2). Under the same level of climate warming, low-intensity agriculture experienced 30% and 23% reductions in insect abundance and species richness, respectively.  This indicates that biodiversity in lower-intensity agricultural systems is partially buffered against the negative impacts of increases in extreme temperature.  Consistent with expectations, the negative associations of abundance and richness with climate change and land use were greater in the tropical realm, whereas positive associations were observed in natural habitats (primary and secondary vegetation) in the non-tropical realm (Fig. 3). This positive relationship with climate change may have occurred at least in part because the most climate-sensitive species have already been lost in non-tropical regions through a long history of land-use change.  The fact that no mitigation by natural habitat was observed for the anomaly based on maximum temperature suggests that natural habitat cannot mitigate increases in extreme temperatures, the occurrences of which are likely to become more frequent in the future. As the global demand for food increases, it is likely that the expansion of agricultural systems will continue. If this agricultural expansion is associated with a reduction in the availability of natural habitats within production landscapes or a move toward higher-intensity agriculture, our results indicate that large declines in insect biodiversity will occur, particularly as climate warming accelerates.  We did not include other aspects of climate such as precipitation here. However, temperature is thought to be a key climatic variable for insect species4.  A quantitative analysis of the impacts of major drivers on global insect diversity has been lacking. Here we show that reductions in insect abundance and richness are greatest in areas of intensive agricultural land use, where the climate includes the warmest temperatures relative to background seasonal and inter-annual variation, particularly in the tropics.  The ability of natural habitats to mitigate the negative impacts of agriculture and climate change in low-intensity agriculture presents a management option that could help to maintain insect populations, although our results suggest that this buffering is less effective against extremely high temperatures.  Mixed-effects models were used to determine the responses of insect species richness and scaled total abundance to land-use and use-intensity classes, climate anomalies and natural habitat in the surrounding landscape. Random effects considered were study, which accounted for differences in sampling methods between studies, and block, as a nested effect within the study effect to account for the spatial arrangement of sites within studies. For the species richness models, site, which is nested within the block effect, was also included as an observation-level random effect to account for overdispersion6,61. Fixed effects considered were standardized temperature anomalies, land-use/use-intensity classification and the proportion of natural habitat in the landscape surrounding the sites. | (Outhwaite et al., 2022) report on the importance of the interaction between land-use change and climate change on impacting insect population trends. Using PREDICTS data from 1992 to 2012, the researchers found that an increase of 1 standard deviation from the baseline temperature in high-intensity agriculture reduced abundance and richness by 49 and 27%, respectively, compared to primary vegetation with no warming. The equivalent figures for low-intensity agriculture were 30 and 23%, respectively. The results indicate that less intensive agriculture partially buffers insects against the negative impacts of climate warming. |
| (Crossley et al., 2020) | 21/4/22 | **No net insect abundance and diversity declines across US Long Term Ecological Research sites**  **Abstract**  We used >5,300 time series for insects and other arthropods, collected over 4–36 years at monitoring sites representing 68 different natural and managed areas, to search for evidence of declines across the United States.  Some taxa and sites showed decreases in abundance and diversity while others increased or were unchanged, yielding net abundance and biodiversity trends generally indistinguishable from zero.  This lack of overall increase or decline was consistent across arthropod feeding groups and was similar for heavily disturbed versus relatively natural sites.  **Intro**  Much evidence for what has been dubbed the ‘insect apocalypse’ comes from Europe11,14, where humans have intensively managed landscapes for centuries and human population densities are particularly high.  Clearly, before concluding that global insect populations are broadly in danger, we will need evidence from diverse communities of arthropods.  This knowledge gap reflects a larger debate about what constitutes convincing evidence for global degradation of plant and animal biodiversity in the Anthropocene23,24.  Here we utilized a geographically and taxonomically broad suite of relatively long-term datasets to search for evidence of insect decline in the United States. The US National Science Foundation initiated the establishment of a network of Long-Term Ecological Research (LTER) sites in 1980, and these now encompass a web of 25 monitoring locations across each of the country’s major ecoregions.  LTER arthropod abundance meta-dataset, 82,777 arthropod observations from 68 datasets were compiled into 5,375 taxa time series spanning up to 36 years, including 48 arthropod orders made up of 1 to 658 taxa in a given dataset.  For each time series, autoregressive models were fit using restricted maximum likelihood to estimate the change in abundance over time.  **Results and discussion**  We found that some arthropod taxa at some sites declined in abundance through the course of their time series, while at other sites a preponderance of taxa increased or there was no clear trend towards increasing or decreasing abundance.  Across all 5,375 time series, 1,738 (~32%) exhibited decreases greater than one standard deviation, 1,303 (24%) exhibited increases greater than one standard deviation and 2,334 (43%) did not change by more than one standard deviation.  Consistent with this, the average abundance trend across LTER sites broadly overlapped with zero.  These patterns were similar when separating taxa into aquatic versus terrestrial arthropods (Fig. 2a) or when separately examining feeding guilds (herbivores, carnivores, omnivores, detritivores, parasites or parasitoids).  Comparison of time series from sites within clearly anthropogenic landscapes with those within more natural sites suggests no overall trend of increase or decline or difference for either broad disturbance category.  In summary, we found no evidence of precipitous and widespread insect abundance declines in North America akin to those reported from some sites in Europe5,6,8,10,12.  Indeed, none of the variables included in the random forests analysis (temperature, precipitation, LTER or start year) could reliably predict the direction or magnitude of abundance trends.  van Klink et al.25 - terrestrial insects have been steadily declining while aquatic insects have been increasing. They found that these trends were strongest in the US Midwest. In stark contrast, we found little consistent degradation of arthropod communities for this same region, despite sharing several LTER sites in common. Four of the five LTER sites included here but not in van Klink et al.25 report increasing arthropod abundances. Measures of total abundance across species can give particular weight to a relatively small number of numerically dominant species. Total grasshopper abundance decreases when species are pooled17, but this pattern is driven by falling numbers of just two once-dominant species.  This pattern highlights the value of reporting multiple biodiversity and abundance metrics and analysing trends at fine taxonomic level (this study) versus broad abundance measurements8,9,25 to gain a more comprehensive picture of overall ecological health.  Particular insect species that we rely on for the key ecosystem services of pollination, natural pest control and decomposition remain unambiguously in decline in North America14,34–36. We know that shifts in species composition can impact ecosystem function even when overall biodiversity and abundance remain unchanged37. Indeed, at least two of the LTER sites were dominated by relatively recently arrived invasive species: soybean aphid (Aphis glycines), which has been a major component of Midwest aphid communities.  **Methods**  For each taxon time series, we estimated a temporal trend using an autoregressive model fit using restricted maximum likelihood. | Crossley et al. (2020) is one of the few studies to report no overall trend in insect abundance and diversity since 1970. The lack of an increase or decrease was consistent across insect feeding groups or the intensity of land-use based on data collected in 68 US long term ecological research sites. Temperature and precipitation were unable to predict the direction of trends. |
| (Dicks et al., 2021) | 21/4/22 | **A global-scale expert assessment of drivers and risks associated with pollinator decline** (expert elicitation)  **Abstract**  We evaluated the relative regional and global importance of eight drivers of pollinator decline and ten consequent risks to human well-being.  Our results indicate that global policy responses should focus on reducing pressure from changes in land cover and configuration, land management and pesticides, as these were considered very important drivers in most regions.  Losing access to managed pollinators was considered a serious risk only for people in North America, whereas yield instability in pollinator-dependent crops was classed as a serious or high risk in four regions but only a moderate risk in Europe and North America.  Perceived risks were substantially higher in the Global South.  **Intro**  There is growing evidence of wild pollinator population declines4,5 and deficits in crop production due to insufficient pollination6 , while global demand for pollination services is at an all-time high7 and likely to continue to grow.  One clear message from the pollination assessment was that evidence on the status and trends in pollinator populations, threats and the impacts of their decline, is concentrated in high-income countries, rather than regions thought to be most vulnerable to decreases in pollinator diversity19 and pollination services2.  Here, we used a structured expert elicitation technique and a globally representative group of 20 pollinator and pollination experts, all authors of this paper, to evaluate the relative importance of eight major direct drivers (or causes) of observed pollinator decline and the risks to human well-being associated with ten direct impacts of pollinator decline defined by the IPBES report1.   * Impacts on food production   + Pollination deficits   + Yield instability   + Honey production   + Food system resilience   + Managed pollinators * Impacts on biocultural diversity   + Wild pollinator diversity   + Wild plant diversity   + Aesthetic values   + Cultural values   Nor did we consider interactions between multiple drivers, despite their likely influence on pollinator decline2 , because knowledge about driver interactions remains largely incomplete and insufficient for the scale and scope of analysis here.  **Results**  Globally, land cover and configuration and land management were the most important drivers of pollinator declines.  Risks were greatest in Latin America compared to other regions with four ‘high’ risks (pollination deficits, yield instability, food system resilience and wild pollinator diversity) and five ‘serious’ risks (all others except managed pollinators). This reflects the high diversity of insect-pollinated crops grown and exported throughout the region, often by smallholder farmers in and around areas of natural habitats that contain a high diversity of pollinating insects46.  Like other regions of the Global South, Latin America is also home to a high diversity of extant indigenous cultures and people, many of whom rely on subsistence agriculture and natural resources such as non-timber forest products47, increasing the risks from a decline in honey, wild fruits and cultural values.  Europe was the region where human well-being was considered at the lowest risk from pollinator declines overall (mean risk score=19.6), with no ‘high’ risks and only two ‘serious’ risks (pollination deficits and wild pollinator diversity). Unlike Latin America, many European countries grow relatively few crops that are highly pollinator dependent and food systems, particularly within the European Union, are highly industrialized and globalized, greatly reducing the importance of wild fruits and buffering against the impacts of global change on food system resilience (both ‘low’ risk).  Subjective due to personal opinions of experts? | From an expert elicitation process, Dicks et al. (2021) concluded land cover and configuration, land management and pesticides to be the main drivers of insect declines.  The risks of insect losses — particularly pollinators — is a particular risk to the global south where a high proportion of insect-pollinated crops are grown, compared to highly industrialised areas of Europe (Dicks et al., 2021). This is a big risk when demand for food is at an all time high.  Expert elicitations are good when data is deficient and could gleam additional insights, though it is subjective due to its basis in personal opinions. |
| (Soroye et al., 2020) | 21/4/22 | **Climate change contributes to widespread declines among bumble bees across continents**  **Abstract**  Using long-term data for 66 bumble bee species across North America and Europe, we tested whether this mechanism altered likelihoods of bumble bee species’ extinction or colonization.  Increasing frequency of hotter temperatures predicts species’ local extinction risk, chances of colonizing a new area, and changing species richness.  Effects are independent of changing land uses.  **Main body**  Identifying which species will most likely be at risk from climate change and where those risks will be greatest is critical to the development of conservation strategies.  Climate change could pose risks to species in part by increasing the frequency of environmental conditions that exceed species’ tolerances, causing population decline and potentially extirpation (6, 7). Conversely, climate change may render marginal areas more suitable for a species, making colonization of that locale more likely.  We predict greater declines in bumble bee species occupancy and species richness where changing climatic conditions more frequently exceed individual species’ historically observed tolerances. Conversely, we predict greater occupancy and species richness in areas where climate changes more frequently cause local weather to fall within species’ historically observed tolerances.  Temperature and precipitation can affect bumble bee mortality and fecundity directly [e.g., (11)] and indirectly through changes to floral resources (12).  Our measurements of bumble bee species occupancy over time provide evidence of rapid and widespread declines across Europe and North America. The probability of site occupancy declined on average by 46% (±3.3% SE) in North America and 17% (±4.9% SE) in Europe relative to the baseline period (Fig. 2).  Evidence for precipitation influencing site occupancy was mixed, but declines were more likely in sites that became drier.  At this scale, effects of climate change on bumble bees appear distinct from effects of land use.  Nevertheless, overall rates of climate change–related extirpation among species greatly exceed those of colonization, contributing to pronounced bumble bee species declines across both Europe and North America with unknown consequences for the provision of ecosystem services. | Soroye et al. (2020) point to climate change as the main driver of bumblebee declines they found across North America and Europe. Increasing occurrence of hotter temperatures was able to predict extinction risk and chance of colonisation. Climate affects species by changing environmental conditions so the temperature exceeds the tolerance of a species, causing extinction or range shifts, or making new areas more suitable for survival. Climate change not only directly affects bumblebees by affecting fecundity and mortality, but also indirectly through alteration to floral resource. |
| (Welti et al., 2021) | 25/4/22 | **Studies of insect temporal trends must account for the complex sampling histories inherent to many long-term monitoring efforts**  Response to Crossley, 2020.  We suggest that Crossley et al.’s results rely on a key, but flawed, assumption that sampling was collected “in a consistent way over time within each dataset”.    Use of unsuitable datasets and not taking sampling effort into account generate erroneous estimates of population change. | Welti et al. (2021) highlight issues with Crossley et al. (2020) in that the results are flawed due to the researchers violating the assumption that records were collected consistently between datasets. |

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