Primary papers and their key findings on insect trends

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| Reference | Taxonomic group | Location | When? | Method | Key findings |
| Hallmann, 2017 | Flying insects | 63 nature protection areas, Germany. | 27 years (1989-2016) | Biomass  Malaise traps | Seasonal decline of 76%, regardless of habitat type, while changes in weather, land use, and habitat characteristics cannot explain this overall decline. Not only vulnerable species |
| Sanchez-Bayo, 2019 | Insects. | Global (but not really) | Compiled all long-term insect surveys conducted over the past 40 years | Review of 73 historical reports. | Dramatic rates of decline that may lead to the extinction of 40% of the world's insect species over the next few decades.  Simmons, 2019 says there are issues with this paper. |
| Powney, 2019 | 353 wild bee and hoverfly species | Great Britain (England, Scotland, Wales) | 1980 and 2013 | Occupancy models | Losses concentrated in rare species. Losses linked to specific habitats – 55% decrease species associated with uplands. 12% increase in dominant crop pollinators.  Third of wild pollinator species (33%) have decreased over this period, approximately a tenth have increased.  Similar overall declines for bees (25%) and hoverflies (24%) but all severe bee decline occurred post 2007, whereas hoverflies declined steadily from 1987 to 2012. |
| Outhwaite, 2020 | Terrestrial insects (also looked at bryophytes and lichens). | UK | 1970-2015. | Occupancy. | Over 5000 species, 11% higher occupancy in 2015 compared to 1970.  Insects show a slight increase in occupancy of 5.5%.  Rare species showed greater change. |
| Biesmeijer, 2006 | Bee and hoverfly | UK and Netherlands. | Before and after 1980 | Rarefaction methods to compare species richness. | Declines more frequent in habitat/food specialists, univoltine species, and/or nonmigrants.  Bees - Signif decreases in richness observed in 52% and 67% of British and Dutch cells. Increases in 10 and 4%.  Hoverflies - No signif directional change for hoverfly richness in UK, but increases in 34% and decreases in 17% of Dutch cells.  Increase in domination of pollinator communities of both countries by smaller number of species. |
| Ollerton, 2014 | Bee and flower-visiting wasps | Britain | Mid 19th century – present. | Historical records  Assessed rate of extinction | From 1920-50s – lost 3.41-3.46 species per decade. From 1960s – 0.98 species per decade |
| Hallmann, 2020 | Beetles, moths, caddisflies | Netherlands | 1997-2017 | Abundance and biomass. | Macro-moths, beetles, caddisflies - Annual rates of decline of 3.8, 5.0 and 9.2%, respectively.  Declines of ground beetles (Carabidae) stronger after 1995.  Abundance measure: Macro-moths - trends of individual species comparable to overall trend BUT ground beetles - abundant performed worse than rare.  Biomass measure: ground beetles - rarer species showed stronger declines, so suggests biomass may not always show one-to-one correspondence to numerical declines  Biomass: 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. |
| Lister and Garcia, 2018 | Arthropods | Puerto Rico rainforest where temps have risen by 2 degrees | 1976-2012 | Dry weight biomass. | Sustained declines (across all 10 of the major taxa captured) over the 2 decades.  Climate warming is the major driver due to average ambient temp being signif predictor in abundance. Also, signif human perturbations have been virtually non-existent. |
| Seibold, 2019 | > 1 million arthopods, 2700 species | Gradients of land-use intensity in 150 grassland, 140 forest sites, 3 regions of Germany | 2008-2017 | Biomass, abundance and number of species | Grasslands - biomass, abundance and number of species declined by 67%, 78% and 34%, respectively. Mainly affected rare species. Sites embedded in landscapes with a higher cover of agricultural land showed a stronger temporal decline  Forest - biomass and species number—but not abundance—decreased by 41% and 36%, respectively. Abundant and rare species affected. Some originally abundant species actually increased in abundance. |
| Gillespie, 2020 | Terrestrial arthropod | North Atlantic region of the Arctic. | >10 years | Abundance and diversity | Signif declines in 7/14 muscid fly species 1996-2014.  Iceland moth monitoring since 1995 shows significant positive trends in species richness at two locations, but negative or non-significant trends in abundance.  1996-2016 – signif declines in total abundance of potential vertebrate prey |
| Homburg, 2019 | Carabid species | Nature reserve in Northern Germany. Woodlands, | 24 years, | Trapping study  Assessed biomass, species richness, functional diversity and phylogenetic diversity. | Did not observe a decline in number of individuals (abundance) or biomass, but in species richness, functional diversity and phylogenetic diversity.  Smaller species showed stronger declines so diversity less represented by decreasing number of small species, maybe explaining why no decline in biomass? |
| Brooks, 2012 | Carabids | UK | 15 years, 1994-2008 | Species declines | Substantial overall declines, ¾ species studied declines.  Differences between regions and habitats – 48.4% declines in northern moorland and western pasture, to 50% increases in southern downland. More stable in woodland and southern hedgerow. BUT even when stable in these sites, same taxa were often declining elsewhere. |
| Fox, 2019 | 54 butterfly and 431 macro-moth species | UK. | 10-year periods, each starting 1 year after the previous one (i.e. 2001–2010, 2002–2011, 2003–2012, 2004–2013, 2005–2014 and 2006–2015). | Extinction status. | Varying the start year of the 10-year population trend had a substantial effect on overall number of species assessed as threatened. |
| Loboda, 2018 | High arctic fly, 18385 individuals, 16 species of muscid flies | Greenland | 2 decades (1996-2014) | Diversity, abundance and composition | Significant decrease of 80% of total muscid abundance.  The number of common/abundant species also decreased significantly.  Some links between composition and summer temp but at species level, most relationships between abundance and climate predictors were not signif.  No change in habitat similarity suggests no biotic homogenization across habitats.  Results suggest change in species composition mainly attributable to decrease in species abundance. |
| Boyes, 2019 | Winners among British moths. 51 successful species | Britain | 1968-1016 | 4.5 million occurrence records | Majority of winners are broadly habitat generalists |
| Van Strien, 2019 | Butterflies | Netherlands, Grassland, woodland, heathland | 1890-2017. | Decline | 80% decline  Strong decline in all 3 habitats.  Stabilized over recent decades in grassland and woodland, but decline continues in heathland. |
| Van Klink, 2020 | Terrestrial and freshwater insects. | 41 countries, 166 long-term surveys | 1925-2018. | Meta-analysis | 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.  Patterns were largely driven by strong trends in North America and some European regions.  Protected areas were over-represented so locations where human land use is most intensive, and thus where the strongest effects on insect trends might be expected, were underrepresented. |
| Wepprich, 2019 | Butterfly. | Ohio | 20 years (1996-2016) | Abundance | 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 are declining.  Trends distributed across the phylogenetic tree.  Univoltine species had more negative pop trends. |
| Soroye, 2020 | Bumble bees - 66 species | Across continents, North America and Europe. | Baseline (1901–1974) and recent period (2000–2014) | Assessed effect of climate change on occupancy. | Increasing frequency of hotter temperatures predicts species’ local extinction risk, chances of colonizing a new area, and changing species richness.  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.  Declines more likely in sites that became drier.  Rates of climate change–related extirpation among species greatly exceed those of colonization. |
| De Palma, 2015 | 257 bee species | 1584 European sites | Sites were sampled since February 2000. | PREDICTS synthetic analysis.  Systematically searching Web of Science.  Abundance and occurrence. | Models where interactions were excluded (additive models) explained 13% and 37% less variation in occurrence and abundance, respectively, than the interactive models did.  Shorter flight seasons – the most important trait in explaining occurrence and abundance patterns – maybe because this trait confers a higher risk of asynchrony with key floral resources?  The effects of ecological traits on species’ sensitivity were not always consistent across land uses. |
| Gray, 2016 | Vertebrates, invertebrates and plants | Global |  | PREDICTS synthetic analysis.  (November 2014 version) | Globally, species richness is 10.6% higher and abundance 14.5% higher in samples taken inside protected areas compared with samples taken outside.  Mostly attributable to differences in land use between protected and unprotected sites.  Analysing only the sites within each study for which land use could be matched across the protected area boundary, we found no significant effect of protection on any biodiversity measure for any management category group, taxonomic group or latitudinal zone. Protected areas are most effective where they minimize human-dominated land use |
| Newbold, 2014 | Inverts, herptiles, mammals, and birds. | Global. | Data were collected since 2000. | PREDICTS synthetic analysis.  Assessed effect of land use on occupancy | Not all species respond equally to land-use change. Large, slower-breeding, less-mobile species that are dietary and habitat specialists are typically more vulnerable to land-use change than other species.  Looked at major land-use type, forest cover, removal of vegetation in the 3 years prior to sampling and human population density.  The probability that species occurred at a site was strongly related to the major land-use type (declined in human-modified habitat), and this response differed markedly among taxonomic groups.  Increased dominance by smaller numbers of taxa.  Most variation remained unexplained. |
| Newbold, 2016b | Invertebrates, vertebrates, plants and fungi | Global. |  | PREDICTS. | Strong impact of land use on assemblage composition.  Effect weaker in temperate compared to tropical. |
| Newbold, 2016a | Plants, invertebrates, and vertebrates | Global. |  | PREDICTS. | Most of the world’s land surface is biotically compromised in terms of BII (Biodiversity Intactness Index). |
| Millard, 2021 | 4502 pollinating species. | Global |  | PREDICTS and new database.  Land-use type and intensity. | Divergent effects between non-tropical and tropical zones. Non-tropical – richness and abundance did not differ significantly among cropland intensity classes. Higher in minimal-intensity cropland than primary vegetation. BUT tropical – richness and abundance decreased between primary vegetation and high intensity cropland. |
| Crossley, 2020 | Insects and other arthropods | US Long Term Ecological Research sites. >5,300 time series.  68 natural and managed areas | 4-36 years.  The US National Science Foundation initiated the establishment of a network of Long-Term Ecological Research (LTER) sites in 1980 | Abundance and diversity | No net insect abundance and diversity declines. |