Extensive climate-induced range shifts in butterflies across the globe

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Abstract

Ongoing global change is leading to widespread species redistribution[1,2]. Range shift attribution, however, remains poorly resolved, partly due to the strong variation in range shift detection signals in space, over time and across the tree of life[2]. We compiled range shift data in 15 languages and with expert assessments, encompassing 1,758 butterfly species from 109 countries (~10% of the known diversity)—a flagship for invertebrate conservation and a charismatic group used as a sentinel of global climate change[3]. Approximately 81% of species expanded their ranges horizontally primarily due to climate change and severe weather. This effect was most prominent in tropical regions, which have largely been neglected in previous studies. A significant proportion of species either contracted their ranges (27% of species) or shifted altitudinally (22% of species). Based on these clear and widespread signatures of global range shifts and their underlying drivers, we call for concerted efforts to include butterflies and other invertebrates in nature and species conservation assessments and national conservation policies. These sweeping strategies should also advocate for increased surveillance and long-term population monitoring of key invertebrate groups globally, which will especially inform and strengthen conservation policy in Tropical countries[4].

Main

Anthropogenic pressures are reshaping species distributions worldwide, directly through land-use changes and indirectly through climate change[1,2,5,6]. They are forcing species to track favourable environmental conditions by shifting their ranges[1,2,7,8,9,10], thereby triggering cascading consequences across ecosystems[2,3,11], resulting in community reshuffling, disrupted coevolved interactions, and undermining conservation efforts[2,11,12]. Ranges may shift longitudinally or latitudinally, leading to both horizontal range expansion and contraction dynamics, as new habitat is gained or lost[13,14,15,16]. The colonisation or extirpation rates of range shifting species largely depend on the interaction between species traits and environmental conditions[3,17,18]. Accordingly, some species can track their available habitats, while others accumulate climatic debts[8,19,20].

Despite the recent increase in range shift reports, our knowledge remains taxonomically and geographically biased[21,22,23]. Nearly half of the published literature on species redistribution comes from Europe[23], with limited insights from tropical regions, where most biodiversity is concentrated[22,24]. A global analysis of 12415 species confirmed this bias: flowering plants represented nearly 40% of the reported range shifts, while for animals, birds and fish were the most assessed groups[2]. Such imbalances cast doubt on the reliability of so-called 'global' summaries, which often overlook regions experiencing rapid environmental changes[22]. The paucity of detailed species distribution data in under-sampled tropical areas and for under-represented taxa hinders our ability to detect species range shifts comprehensively, understand their underlying drivers, and discern their consequences for global biodiversity and conservation[16,25].

To address these limitations, we initiated an extensive collaborative effort to integrate existing datasets with non-traditional data sources in 15 languages and 68 expert assessments. We focus on butterflies – the very first group used as a sentinel to detect the first comprehensive range shifts signals in response to climate change[3]. Butterflies (~19000 species) occupy diverse zoogeographic regions, altitudes and habitats[29], and their reliance on a narrow range of larval host plants and thermal tolerance, relatively high dispersal capacity, and short lifecycles, render them a highly effective early warning system for detecting the biological impacts of environmental change[28,30,31,32]. We focus on three main types of range shifts: horizontal range expansion, horizontal range contraction, and elevational range shifts (Table 1). We first document these range shift patterns before assessing which threats underpin butterfly species range shifts. Finally, we highlight priorities for future research and conservation.

Global research effort in studying butterfly species range shifts

Our dataset comprises 6182 range shift reports from 565 unique studies and 68 expert assessments, covering 1758 species across 109 countries (Figure 1A-D; Extended Data 1) from every continent where butterflies occur[29]. These reports 10% of the butterfly species (n = 19394)[29] from six major butterfly families (Figure 1E). We gathered records on horizontal range expansions for 1426 species from 106 countries (Figure 1B), horizontal range contractions for 479 species from 47 countries (Figure 1C), and elevational range shifts for 380 species from 29 countries (Figure 1D).

Horizontal expansions were reported across all continents, with particularly high from the Tropics (e.g., Brazil, Benin) (Figure 1B), challenging the most recent synthesis claiming little evidence for range expansions in the tropics[16]. One potential reason for the higher number of range expansion reports we found in the Tropics could be due to the inclusion of the scientific literature published in languages other than English[4,33], as well as the support from several international experts on butterflies. In contrast, horizontal range contraction reports were far less common outside of Europe and North America, with the highest of reports being concentrated in temperate countries (e.g., Belgium, United Kingdom, Sweden; Figure 1C)[34,35,36]. Elevational shifts were detected across tropical, temperate and boreal regions but almost exclusively from the Northern Hemisphere (Figure 1D). However, there were substantially fewer reports of elevational range shifts in the Tropics despite temperature declining faster with elevation in these regions and steeper adiabatic lapse rates, which would theoretically facilitate faster upslope movements in response to warming[10,11,37].

We also recorded substantial differences in the taxonomic coverage. Relative to the total number of known species per family, nymphalids had the highest percentage of species shifting their ranges, while riodinids had the lowest (Figure 1E). In both relative to the total number of butterfly species for the focal family and relative to the total number of species for which we found evidence of range shifts (n = 1758), the highest percentages were always reported for horizontal range expansions and the lowest ones for elevational range shifts (Figure 1E).

There was also a clear imbalance among species regarding reporting intensity: 65% of species had a single record of range shift from a single study and country (Figure 1A). Only 102 species (6%) had more than 10 independent reports of different range shifts from at least 10 different studies, with 66% of these range shifts' records being related to horizontal range expansion. Only two species (*Aphantopus hyperantus* and *Parnassius apollo*) had multiple records of elevational range shifts across multiple studies (Figure 1A). For example, *Araschnia levana*, *Boloria selene*, and *Aphantopus hyperantus* had the highest number of records for horizontal range expansion (n = 34), contraction (n = 25), and elevational range shift (n = 13), respectively, and in many cases, these records were from different regions. For four species (*Vanessa cardui*, *Nymphalis antiopa*, *Gonepteryx rhamni*, and *Anthocharis cardamines*), we gathered records of both upslope and downslope elevational range shifts.

Spatial patterns of butterfly species range shifts' detection

We detected strong geographical variation in the percentage of butterfly species shifting their ranges (Figures 2, 3). When considered relative to the species pool (i.e., the total number of butterfly species known to science, as reported in Pinkert et al.[29]), five European nations (i.e., Sweden, the Czech Republic, Finland, Luxembourg, and Spain) dominate, each having records for >50% of their butterfly fauna (Figure 2). Conversely, in most countries, the documented shifts affected <10% of the national butterfly species. Among range shift types, Sweden reported the highest taxonomic representativeness for reports on expansion (61%), while the Czech Republic and Estonia had the highest percentages of contraction (63%) and elevational shifts (35%), respectively.

To better address sampling gaps in countries, we calculated the percentage of butterfly species per country for which we have range shift data, but this time relative to all butterfly species in that country that have been reported to shift their range either locally in the focal country or elsewhere in other countries. For 32 countries from all continents, at least 25% of the butterfly species have experienced a range shift, and in 10 countries, this was true for >50% of the species (Figure 3). The highest percentages appeared in Sweden (78% for horizontal range expansions), the Czech Republic (85% for horizontal range contractions), and Estonia (44% for elevational range shifts).

Most species (80%) had records for a single type of range shift in our dataset—typically horizontal range expansions (70%). However, 342 species (19%), especially in Europe and parts of South America, displayed multiple records covering multiple range shift types, such as both horizontal range expansions and contractions, either within a country or across different countries. For example, *Danaus plexippus* experienced range contraction in the United States, but range expansion in Spain, while *Aporia crataegi* experienced both range expansion and contraction in Andorra. These multi-dimensional shifts highlight the complexity of biotic responses to ongoing environmental pressures, and underscore the importance of distinguishing between the different types of range shifts when assessing biodiversity redistribution[21].

We pinpoint where and how butterfly ranges are changing globally and highlight the urgent need for equitable and standardised monitoring. The density of European records reflects both genuine changes and stronger detectability of range shifts given long-term biodiversity monitoring programs, whereas lower records from the Tropics likely reflect data scarcity rather than an absence of biotic responses. Despite representing a significant portion of the world's butterfly diversity, regions such as Central Africa, Southeast Asia, mainland New Guinea and its surrounding islands, and the Amazon Basin remain markedly underrepresented. In many tropical studies, range shifts were simplified as expansion or contraction when species newly appeared or disappeared locally (Table 1), obscuring exact patterns. This is worrying because tropical species are especially vulnerable: they already live near their upper thermal limits, have restricted ranges, and are isolated from cool refugia[38,39]. Elevational shifts are also more commonly reported for tropical insects than poleward range shifts[40], which contrasts with former reports from Colwell & Feeley[16]. Recent work suggests a major erosion of the future geographical extent suitable for butterfly species according to their thermal niches, with up to a 64% loss projected by 2100, even when assuming full dispersal within biogeographical realms[41]. This implies major range contractions and particular vulnerability of rare tropical species at higher elevations.

Drivers of butterfly range shifts

We compiled threat data linked to butterfly range shifts from 70 countries. For example, *Boloria aquilonaris* has lost much of its original habitat in Germany due to bog drainage (i.e., habitat loss and degradation)[42], while in Romania, habitat homogenisation and agricultural intensification caused a severe range contraction for *Colias myrmidone*[43]. In Brazil, *Godartiana byses* has expanded its horizontal range from the states of Rio de Janeiro and Bahia to São Paulo in response to climate warming[44]. Biological invasions also explain range shifts for some of the studied butterfly species. For instance, the introduction of *Pieris rapae* led to dramatic range contractions of *Pieris oleracea* in the United States[46].

We categorised threats following the IUCN threat categories (see supplementary methods). Overall, we identified nine primary threats that were directly or indirectly related to butterfly range shifts. *Climate change and severe weather* had the greatest impact (277 of 256 species with threat data), while *energy production and mining* had the least reported impact (three species; Figure 4A). Though not always supported by formal analyses, *climate change and severe weather* was linked to 163 species' horizontal range expansions, 131 species' horizontal range contractions, and to 61 species' elevational range shifts (Figure 4A). The relative importance of different threats varied across range shifts. While *human intrusions and disturbance*, and *agriculture and aquaculture* were the dominant drivers associated with horizontal range contraction, both affecting 143 species, *climate change* *and severe weather* were the dominant drivers linked to elevational range shifts, affecting 61 species. These elevational range shifts are particularly important as butterfly species richness, endemism, and phylogenetic diversity are highly clustered in mountainous regions worldwide. Approximately two-thirds of all butterfly species are primarily mountain-dwelling species, but mountain climates are rapidly eroding in the face of climate change[41].

In most continents, *climate change and severe weather* were reported to have the highest impact, whereas *residential and commercial development*, as well as *invasive and other problematic species, genes and diseases* were the most prevalent threats in Oceania, and *human intrusions and disturbance* were dominant for South America (Figure 4B). *Climate change and severe weather* were consistently linked to horizontal range expansions in all continents, while several other threats were linked to horizontal range contractions in different continents (Figure 4B). While there were one or two major threats in most continents, like in Europe, several threats concurrently impacted horizontal range expansion and contraction (Figure 4B).

These patterns highlight diverse pressures and the need for region-specific conservation interventions. Species experiencing both horizontal range expansions and local adjustments through elevational range shifts may require improved connectivity – a direct action in the RAD framework[47], whereas contracting species may benefit from targeted protection and restoration – resist actions[47,48,49]. Range expansions are often facilitated by rising temperatures, enabling cold-limited species to colonise higher latitudes or elevations. Conversely, range contractions are typically linked to land-use change, especially habitat loss, with species unable to persist in increasingly modified environments. Threat impacts are often population-specific and strongest near range margins where physiological limits are approached[50].

Minimising drivers of range shifts to mitigate butterfly decline

Our dataset confirms pioneering studies on range shifts, that butterflies tend to expand more than they contract their ranges[3,8]. This is likely due to their phenotypic plasticity, which allows local populations to survive a supposed decline in areas near the range margin by adopting opportunistic or behavioural strategies[51,52,53]. Range shifts in butterflies can be restricted by host-plant availability, habitat fragmentation, or limited dispersal across islands and mountain tops[3,54,55]. Habitat heterogeneity is therefore crucial to provide refugia and buffer populations against abrupt losses[56,57].

Climate change mitigation remains central to minimising the climatic debt – the lag between shifting isotherms and population responses. Even small temperature increases may exceed physiological limits, alter seasonal phenology, or disrupt biotic interactions with host plants and mutualists[32,58,59]. For example, with rising temperatures, Scandinavian butterflies have expanded northwards[31,60], whereas alpine species are being squeezed towards mountaintops[61]. Limiting global warming will be crucial for maintaining accessibility to thermally suitable habitats and avoiding range shift gaps[40]. Across Europe and South America, butterflies retreat to shaded or forested areas on hot days[51,62,63,64], highlighting the role of microrefugia. Because the 2°C threshold outlined during the Paris Agreement becomes increasingly unachievable[65], conservation must pair mitigation with adaptation—such as protecting microrefugia[66], buffering habitat edges, and improving landscape connectivity—to build resilience[49,67,68].

Equally important is the protection and restoration of habitat quality. Land-use change—including agriculture, aquaculture, and urban development—is a leading cause of horizontal range contractions in butterflies (Figure 4)[34,69,70]. Habitat degradation decreases the availability of crucial host plants, nectar sources, and microclimates necessary for butterfly survival[71,72]. Protecting intact patches, restoring degraded sites, and connecting landscapes can enable recolonisation and sustain genetic diversity[30,73,74,75,76]. Even small, well-managed patches enhance metapopulation persistence when total habitat area is sufficient[55,76].

Other anthropogenic pressures, such as urbanisation, roads, invasive species, and chemical use, further restrict movement and degrade habitats[17,73,74,77,78,79,80]. Integrating biodiversity goals into infrastructure and land-use planning—through ecological corridors, stepping stones, and robust environmental assessments—can sustain connectivity[48,76].

Finally, building ecological resilience is essential for long-term stability[81]. Diverse, structurally complex ecosystems can better withstand disturbance and maintain genetically robust butterfly populations. Conserving diverse populations and their biotic interactions lowers the risk of range contractions while facilitating adaptive shifts[74,82,83]. In the Brazilian Atlantic Forest, landscape composition and configuration were as important as climate in shaping local butterfly diversity, with forest loss posing the greatest threat[84].

Overall, minimising the drivers of range shifts requires an integrated approach that connects climate mitigation, habitat protection, sustainable land management, and coherent policy action to prevent biodiversity loss in a rapidly changing world.

Future monitoring and conservation prospects

Geographic and taxonomic biases significantly influence biodiversity assessments and conservation strategies[22,85]. The perceived dominance of reports on horizontal range expansions might be partly influenced by detection and reporting biases rather than by actual ecological trends. If horizontal range contractions and elevational range shifts are not adequately documented in tropical regions—where the impacts of climate change and land-use pressures are very severe—we would greatly underestimate the vulnerability of tropical butterflies[15,16,86,87].

To close this gap and advance the field, we propose a three-fold applied framework: (i) expanding monitoring programs in underrepresented regions, (ii) integrating citizen science and local knowledge, and (iii) accounting for species range shifts in conservation planning.

Step I. Expanding monitoring programs in underrepresented regions

Long-term monitoring in Europe and North America has revolutionised our understanding of butterfly responses to environmental changes (e.g.[88,89,90]). However, such programs are scarce in the Tropics, arid, and semi-arid regions[87,91], limiting our understanding of species response to global change[92]. For one third of all butterfly species, not even a single occurrence record is currently available[41]. We urgently need to expand monitoring biodiversity programs in underrepresented regions, supported by international collaboration and local capacity building[4,22,93,94,95]. This includes prioritising biodiversity hotspots and elevational gradients that may be particularly sensitive to climate change. Digitising museum and private collections can recover historical data and extend temporal coverage[56,96], while including local-language and non-indexed publications can reduce geographic bias. These efforts will help reconstruct historical range boundaries and bridge spatial and temporal data gaps.

Step II. Integrating citizen science data and local knowledge

Citizen science platforms such as iNaturalist and national biodiversity portals have rapidly expanded occurrence data, but remain geographically skewed[4,97,98]. Community-led initiatives and local partnerships can improve data validation and coverage[4,97,99,100,101,102]. In Brazil, the knowledge on the area of occupancy of over 70% of threatened butterfly species improved through citizen science efforts[103,104]. In Bangladesh, 93% of butterfly occurrence records originated from Facebook photographs[105], revealing that one-third of Bangladeshi butterflies could go extinct under future climatic scenarios[15], while in the Philippines, citizens documented many rare and elusive butterfly species[106].

These examples demonstrate a huge untapped potential, but also highlight the need to explore alternative and complementary monitoring approaches. This could possibly be achieved through a combination of structured transect walks, time-bound counts (e.g., 15 min) and fruit baits for forest areas—but other approaches may need to be explored. Incentivising participation through recognition or microgrants can further boost engagement[107,108]. Embedding citizen science in national biodiversity strategies will help track progress toward post-2020 Global Biodiversity Framework targets and enhance conservation literacy[109,110,111].

Step III. Accounting for species range shifts in conservation planning

Despite mounting evidence of species range shifts, conservation frameworks rarely consider range dynamics, limiting their applicability and ability to protect biodiversity under climate change. While protected areas have been established to insulate species from various direct threats[112,113], 76% of insect species are inadequately represented within the current protected area system[114]. The situation is worse for migratory butterfly species, with 85% being inadequately protected[115]. To address these limitations, conservation planning should incorporate real-time species range shift data[35,116]. Aligning national efforts with the Kunming-Montreal Global Biodiversity Framework will require systematically incorporating range shift data into inform spatial planning, monitoring, and progress reporting[117]. Existing tools such as the IUCN Red List rely on static maps, with most threatened insects listed under restricted-range criteria (B or D2) rather than population decline (A)[118].

Species facing contractions or elevational shifts need targeted interventions, such as maintaining elevational connectivity, restoring refugia, or establishing transboundary corridors. Lastly, scenario-based forecasting using species distribution models can be a powerful tool for proactive conservation planning, especially so for data-poor species or for tracking species niche, assessing species vulnerability to global change, prioritising future conservation areas, restoring stepping-stone habitats, or establishing transboundary agreements for migratory or shifting species[118,119,120].

Ultimately, conservation needs to shift from reactive to adaptive approaches, adopting predictive modelling and including species range dynamics in policy and practice.

Conclusion

Butterflies are a highly diverse and widely distributed group, contributing to many ecosystem services and serving as biological indicators. We report that globally, the current detection rate for butterfly species range shifts affects one in ten species, often involving *climate change and extreme weather*, along with *agriculture and aquaculture* and *human intrusions and disturbance* as the most likely drivers of butterfly redistribution. Despite our efforts to build the largest dataset compiling reports of range shifts in butterflies, our understanding of how butterflies respond to global changes remains biased towards temperate species, with many species, especially in the Tropics, lacking detailed data. Expanding biodiversity monitoring, including citizen science approaches and accounting for range dynamics in conservation, will enhance our understanding of butterfly responses to environmental change and aid in developing more adaptive, forward-looking conservation strategies. Without such global, coordinated efforts, we risk missing early warning signals of biodiversity collapse—especially in regions and for taxa that are underrepresented in existing data repositories. Considering that many other taxa are experiencing similar shifts in their geographic ranges, our methods and recommendations are transferable to other taxonomic groups and scalable across terrestrial and marine realms to understand how biodiversity responds to global change drivers and thus work jointly towards effective conservation and restoration.

Methods

We followed two primary steps to extract data on butterfly species range shifts. First, we reviewed the published literature. Then, to account for the widely acknowledged bias in the published literature, we invited 68 butterfly experts, all co-authors, from 49 countries to fill this knowledge gap.

As many authors published their research in non-English languages[33,121], we searched for published literature in 15 languages (see supplementary Table S1). For English-language studies, we used Web of Science and Google Scholar, while for studies published in non-English languages, we used Google Scholar and local search engines available within the focal country (see supplementary methods).

We used the same standardised template form (see supplementary methods) to extract information at the study level or at the expert level, depending on the two above-mentioned steps. We contacted the IUCN SSC Butterfly and Moth Specialist group and the Butterfly Conservation group to compile a list of butterfly experts who have been doing field work for many years. Once each expert agreed, we asked them to share the same type of range shift information and to fill the same form by providing the type of range shift (i.e., distinguishing between horizontal range expansion, horizontal range contraction and elevational range shifts) (see Table 1), an information that was either reported by a given study or that was assessed directly by our set of butterfly experts who relied on field observations. Specifically, the experts compared the area of occupancy maps covered by field observations (see Table 1) to determine whether there has been a change in the species range.

Once the data collection was completed, we computed the cumulative sum of reports on range shifts for each country, species, and range shift type, separately from both the published studies and the expert assessments, to understand the global patterns of range shifts in butterflies. Finally, we used the most comprehensive and recent taxonomy of butterflies[30] to match range shift information and country-level distribution data.

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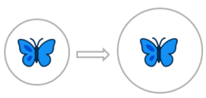
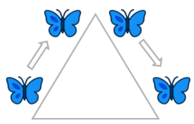
List of table

Table 1. Types and definitions of range shifts considered in this study, including examples from butterfly species. We define *range shifts* as partial changes in species distributions along the latitudinal and longitudinal dimensions (i.e., horizontal range shifts) as well as along elevational gradients (i.e., vertical range shifts), rather than complete shifts of entire populations from one location to another. Here, area of occupancy is defined as the area within its 'extent of occurrence' which is occupied by a taxon, excluding cases of vagrancy[124].

Range shift type	**Definition**	**Example**
 Range expansion	The process by which a species' range expands horizontally by colonising new locations and establishing viable populations beyond the margins of its original area of occupancy[122]. To be inclusive, we considered species new to a region as range-expanding species.	Between 2012 and 2019, *Acraea terpsicore*, native to the Indian subcontinent, expanded its geographic range at 135 km/year in Australia[17].
 Range contraction	The process by which a species' range contracts horizontally by going locally extinct (i.e., extirpation) in parts of its original area of occupancy[122]. To be inclusive, we considered species that became extirpated from a region as range-contracting species.	Over the last 150 years, *Cupido minimus* has lost 40% of its habitat in the UK[123], leading to severe horizontal range contraction along the latitudinal gradient of the UK.
 Elevational shift	The process by which a species' moves to higher or lower elevational areas (e.g., shifting its upper elevational limit, its optimum elevation or its lower elevational limit either upslope or downslope), compared to its original elevational range[7].	Between 1988 and 2011, *Vanessa cardui* experienced a range shift towards higher elevations at a rate of 83 m/year in Mexico, while *Danaus gilippus* shifted towards lower elevations at a rate of 32 m/year[86].

List of figures

Figure 1. Global spatial patterns of range shift reports (n = 6182) stemming from 565 unique studies and 68 expert assessments. The cumulative number of reports is displayed per country (A-D) as well as per family (E). The colour legend on the maps at the country level (A-D), in log scale, shows the number of studies (including expert assessments) reporting range shifts for butterflies, where 0 means that we did not find any study reporting range shifts for any butterfly species within the focal country (shown in white). Histograms next to the maps depict the cumulative evidence of range shift reports, measured as the number of studies for which a given species had been reported to shift, with a clear bias towards single-study reports for a majority of butterfly species and a few cases of butterfly species being reported to shift their ranges from multiple sources: 2, 3 or even more than 3 distinct studies in rare cases. At the family level, we calculated both (1) the percentage of butterfly species covered by our dataset relative to the total number of butterfly species known to science for the focal family (i.e., empty circles) and (2) the percentage of butterfly species shifting their ranges within the focal family relative to the total number of species shifting their ranges in our dataset (n = 1758).

Figure 2. Proportion of range shifting species within each country relative to the total number of butterfly species known to occur within the focal country[29], with 0% indicating that we did not obtain any range shift data from the focal country (shown in white). High values in Europe reflect both genuine change and the much greater probability of detecting range shifts given long-term programs; lower values in many tropical countries likely reflect data scarcity rather than the absence of range shifts for butterfly species.

Figure 3. Proportion of range shifting species within each country relative to the total number of range shifting species which were reported to have experienced range shifts either in the focal country or elsewhere across our dataset, with 0% indicating we did not obtain any range shift data of any butterfly species in the focal country (shown in white). High values in Europe reflect both genuine change and the much greater probability of detecting it given long-term programs; lower values in many tropical countries likely reflect data scarcity rather than the absence of range shifts for butterfly species.

Figure 4. Distribution of threats attributed to butterfly species range shifts (compiled from published literature and experts' knowledge). (A) Summary of the identified threats underlying butterfly species range shifts, where each bar shows the number of butterfly species for which range shifts were attributed to a given threat, and their distribution per continent (B). Here, 'threats by species' indicates the number of times the threat was reported in a given species-by-continent combination. Labels refer to *Climate* = climate change and severe weather, *Agriculture* = agriculture and aquaculture, *Intrusion* = human intrusions and disturbance, *Development* = residential and commercial development, *Transportation* = transportation and service corridors, *Modifications* = natural system modifications, *Invasive* = invasive and other problematic species, genes and diseases, *Resource use* = biological resource use, and *Energy* = energy production and mining.

949 **Figure 1**

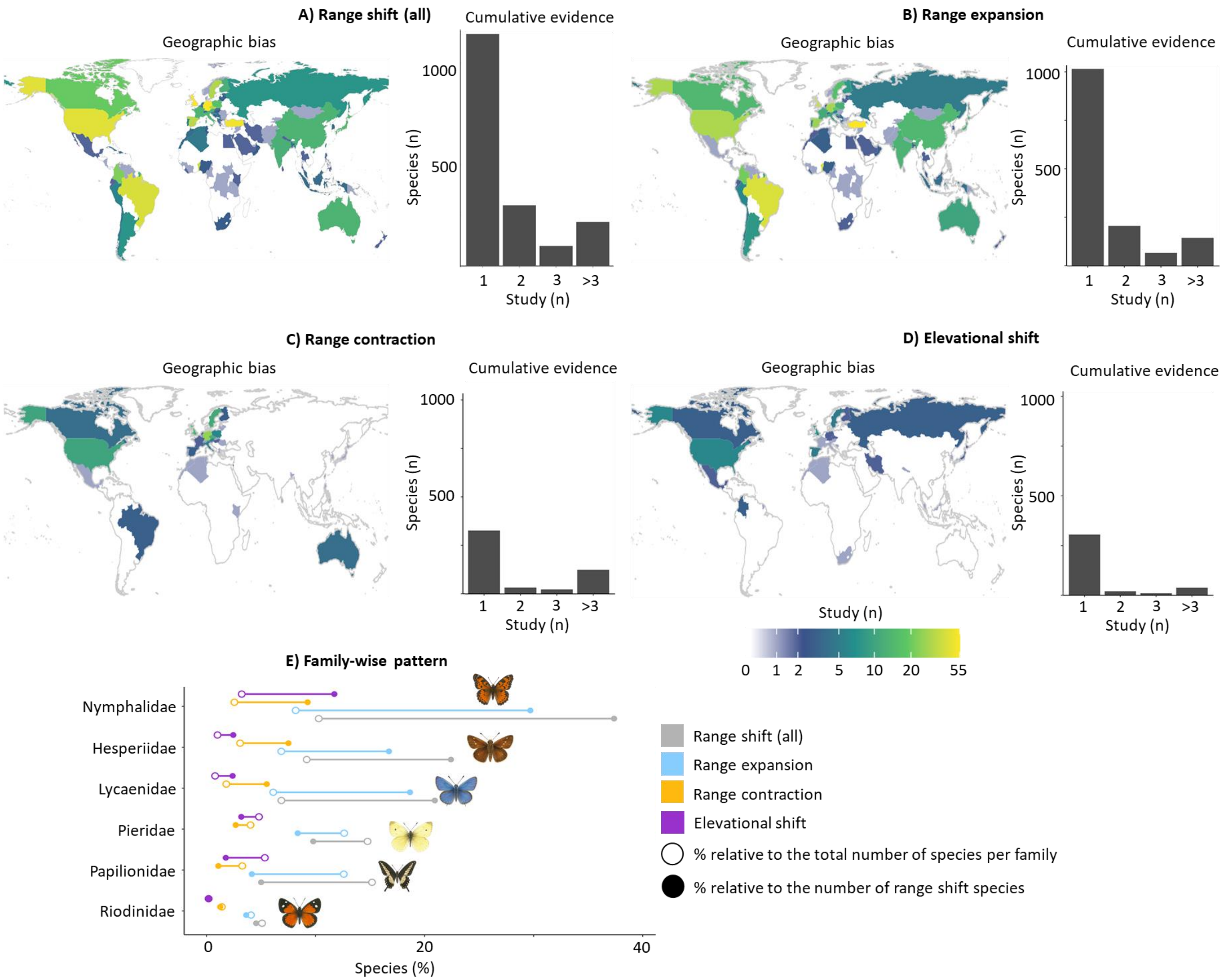


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Figure 2

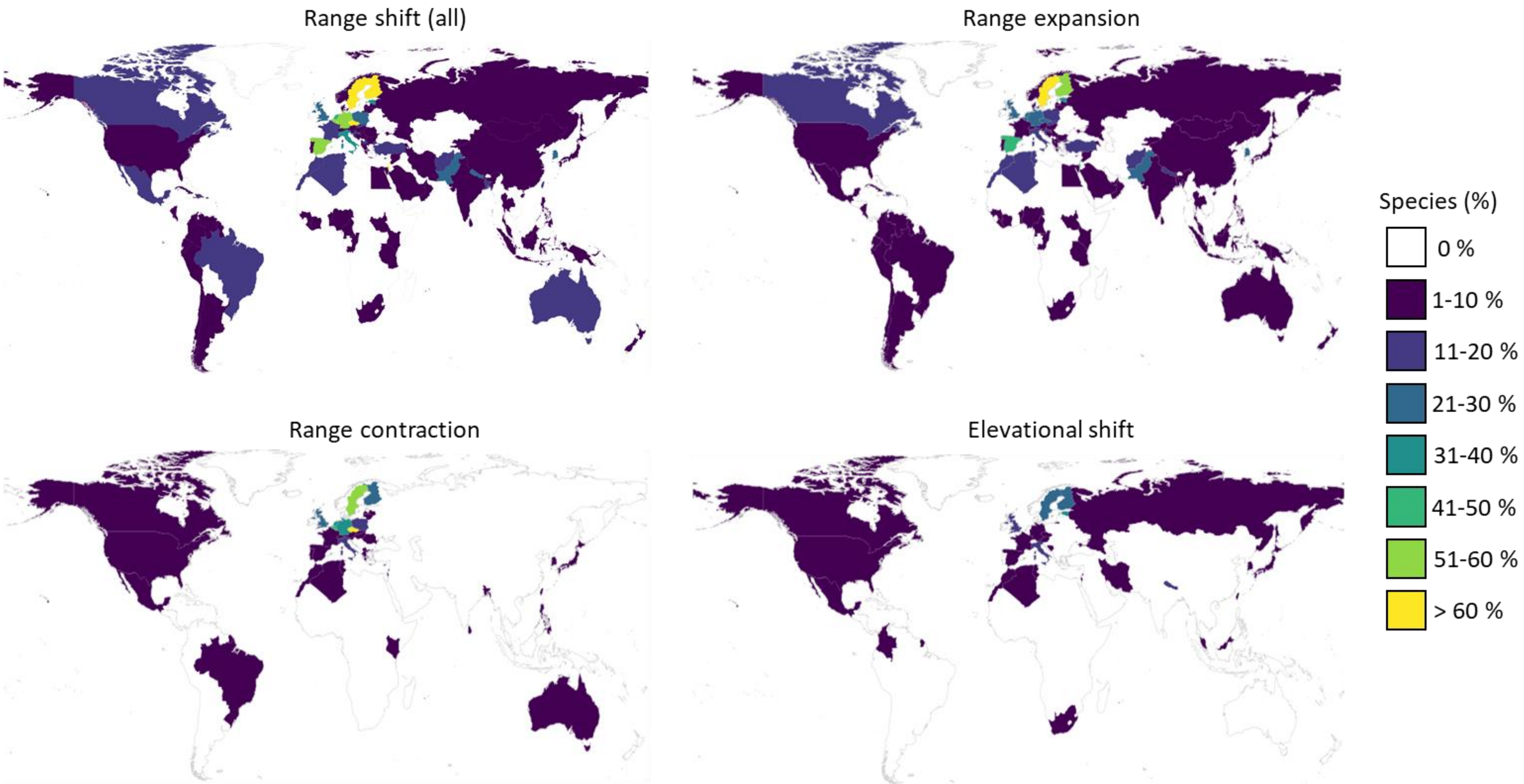

Range shift (all)
Range expansion
Range contraction
Elevational shift
Species (%)
0 %
1-10 %
11-20 %
21-30 %
31-40 %
41-50 %
51-60 %
> 60 %

Figure 3

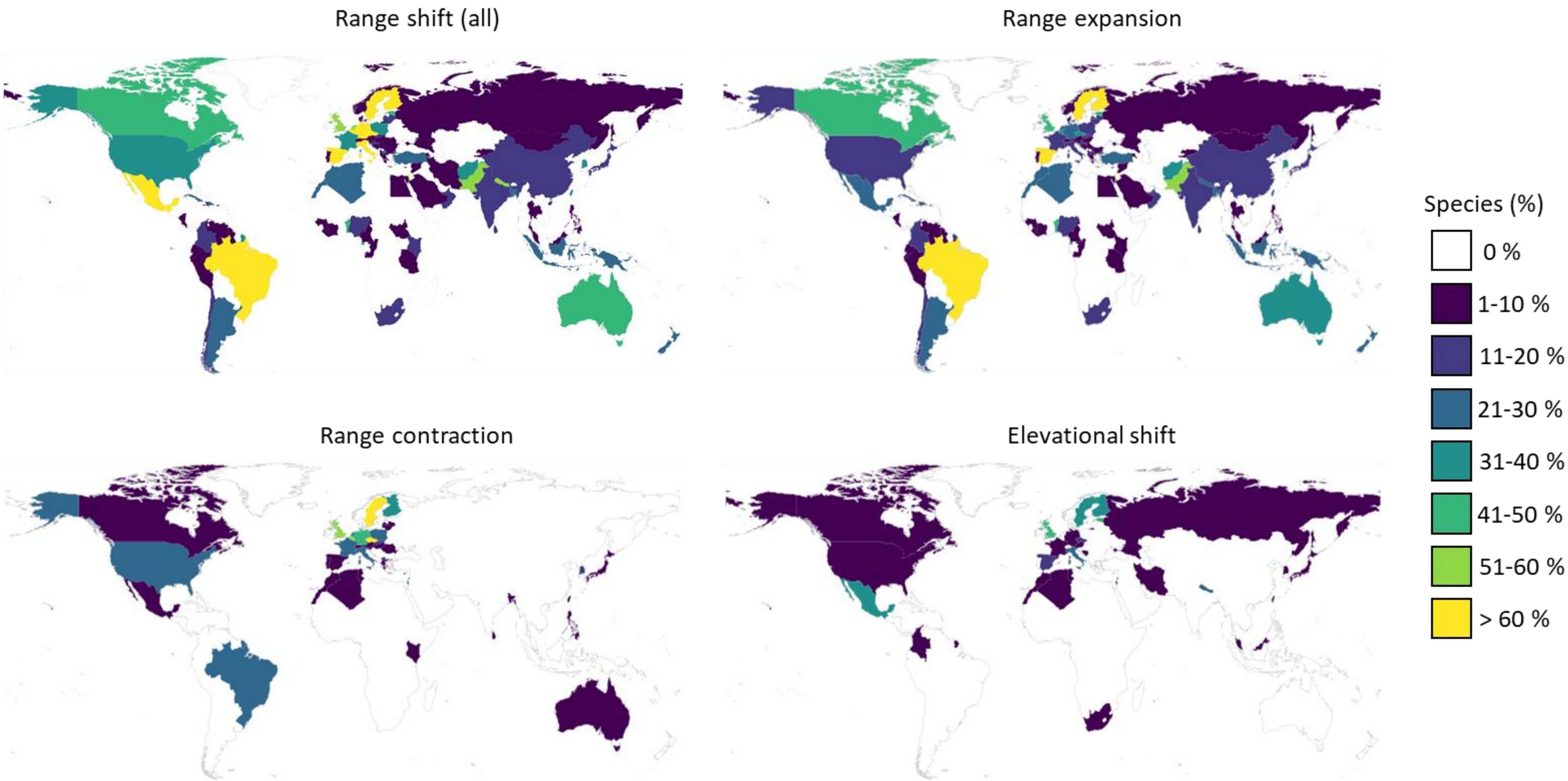
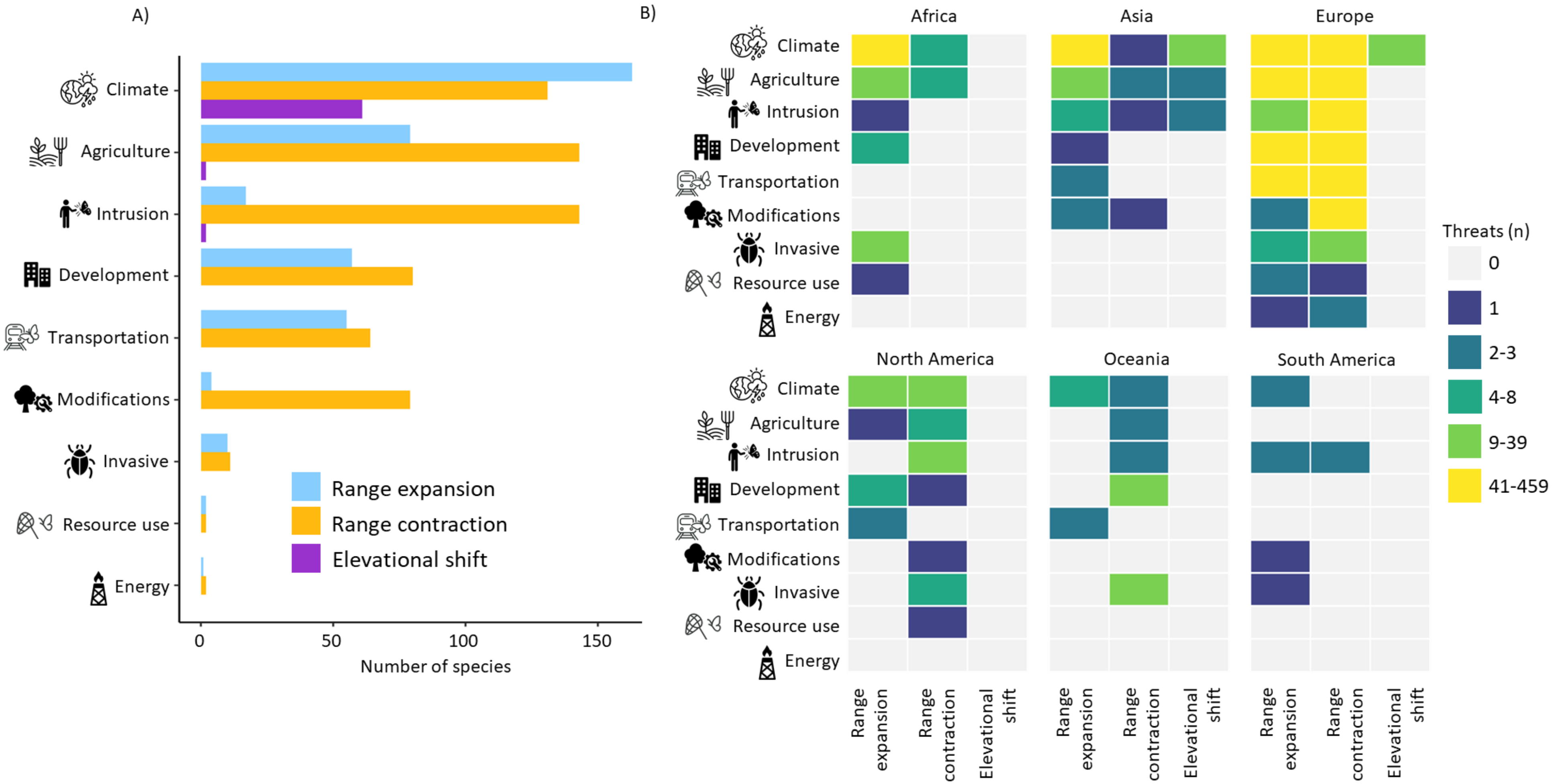

Range shift (all)
Range expansion
Range contraction
Elevational shift
Species (%)
0 %
1-10 %
11-20 %
21-30 %
31-40 %
41-50 %
51-60 %
> 60 %

Figure 4



A)
Climate
Agriculture
Intrusion
Development
Transportation
Modifications
Invasive
Resource use
Energy
Range expansion
Range contraction
Elevational shift
0
50
100
150
Number of species
B)
Africa
Asia
Europe
North America
Oceania
South America
Threats (n)
0
1
2-3
4-8
9-39
41-459
Range expansion
Range contraction
Elevational shift

Supplementary methods

We followed two primary steps to extract data on butterfly range shifts. First, we reviewed published literature. Recognising the language and geographical bias in published literature, we invited 68 butterfly experts (co-authors) from 49 countries.

We conducted a comprehensive search to compile the published literature on butterfly range shifts. As international search systems only capture studies from selected journals, and many researchers publish their research in local journals or even non-peer-reviewed outlets, such as newsletters[1], we searched for published literature in both local and international search systems. We repeated the search for English and 14 other languages (Bahasa Indonesia, Bahasa Melayu (Malay), Chinese (Simplified), Chinese (Traditional), French, German, Hebrew, Japanese, Korean, Persian, Polish, Portuguese, Spanish, and Swedish). Given that our understanding of species distribution was limited before 1990, we considered published resources from 1991 onwards.

We started our search using the Web of Science (using the University of Queensland IP address; Core Collection with KCI (Korean Journal Database), MEDLINE, Preprint Citation Index, and SciELo Citation Index). We used the following search key string:

TS= ((“butterfl* OR "Rhopalocera" OR "Papilionoidea" OR "Nymphalid*" OR "Papilionid*" OR "Lycaenid*" OR "Hesperiid*" OR "Pierid*" OR "Riodinid*") AND ("range" OR "shift" OR expan* OR contract* OR "distribution" OR "invasion" OR “new butterfly”)).

We filtered literature using the following Web of Science categories: Ecology, Entomology, Biodiversity Conservation, Evolutionary Biology, Zoology, Environmental Sciences, Multidisciplinary Sciences, Plant Sciences, Biology, Biochemistry, Molecular Biology, Genetics, Heredity, Behavioural Sciences, Forestry, Agronomy, Environmental Studies, Developmental Biology, Urban Studies, Geography, and Remote Sensing. Overall, we obtained 5,499 studies from the Web of Science.

We further explored relevant studies using Google Scholar. We used the following seven keywords: “butterfly range change”, “butterfly range expansion”, “butterfly range contraction”, “butterfly distribution change”, “butterfly range shift”, “butterfly invasion”, and “new butterfly”. For each search keyword, we reviewed the first 200 articles filtered by relevance (20 pages, with ten articles on each page). As we searched for non-English language studies separately, we restricted our search to English-language studies only. We downloaded the HTML page for the search results of each keyword and used the ‘litsearchr’ R package[2] to extract the publication information for all 1400 studies. We used Rayyan (https://rayyan.ai/)[3] to screen the titles and abstracts. We uploaded all studies, obtained from both Web of Science and Google Scholar, to Rayyan, resulting in 6,899 studies.

We followed two steps when searching for literature in non-English languages. For Google Scholar, we translated English keywords, restricted the language, and searched for relevant studies (Supplementary Table S1). Similar to English-language literature, we considered the published literature between 1991 and 2022, as well as the first 200 articles (up to 20 pages, with ten articles on each page).

Considering that many non-English language studies are not available in international search systems, we further explored language-specific search systems. Here, we translated English keywords and searched for relevant studies in language-specific search systems—if available (Supplementary Table S1).

To include/exclude a paper, we read the title and abstract of each paper. We excluded papers if we could not find any information about changes in the geographic range of butterflies. We also excluded papers if the authors discussed range shift from a meta-population perspective (i.e., from one patch to another), if the paper focused on future range shifts (predicted changes in suitability), or if the paper discussed postglacial range expansion.

From each paper, we extracted the publication information (e.g., journal, DOI), taxonomic details (e.g., species), geographic information (e.g., location), type of range shift (e.g., expansion/contraction), the reasons behind the range shift (as stated by the authors and the experts), whether the species is invasive, the impact on native species, and whether the species is facing any threat. We categorised threats using the IUCN Threats Classification scheme[4] (Version 3.3).

We followed the same format when we invited the experts to share their data. We contacted the IUCN SSC Butterfly and Moth Specialist group (https://iucn.org/our-union/commissions/group/iucn-ssc-butterfly-and-moth-specialist-group) and Butterfly Conservation (https://butterfly-conservation.org/) to compile a list of butterfly experts who have been doing field work for many years. When emailing the experts, we also requested them to share our study with their network so that we can reach the maximum number of people. Once each expert agreed, we requested them to share the same range-shift information, which we obtained from published studies, but based on their field surveys. This way, we obtained expert data from 49 countries.

Once the data collection was done, we aggregated both the datasets from published studies and expert assessments to understand the global patterns of range shifts in butterflies. Finally, we used the most comprehensive and recent taxonomy of butterflies (Pinkert et al. 2022) to match range shift information and country-level distribution data. The total count of species per family based on this source was: 6387 species of Nymphalidae, 5364 species of Lycaenidae, 4290 species of Hesperiidae, 1571 species of Riodinidae, 1165 species of Pieridae and 580 species of Papilionidae, respectively. For our analysis, we excluded Hedylidae (37 species) - American moth-butterflies - whose taxonomic status has long been debated, traditionally leading to their omission from butterfly literature.

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Supplementary Table S1. Search details.

Language	Keywords in English	Keywords in non-English	Search system	URL
Bahasa Indonesia	butterfly range change	Perubahan area/daerah/wilayah jangkauan kupu-kupu	Google Scholar	https://scholar.google.com/
Bahasa Indonesia	butterfly range expansion	Perluasan area/daerah/wilayah jangkauan kupu-kupu	Google Scholar	https://scholar.google.com/
Bahasa Indonesia	butterfly distribution change	Perubahan distribusi/persebaran kupu-kupu	Google Scholar	https://scholar.google.com/
Bahasa Indonesia	butterfly invasion	Invasi kupu-kupu	Google Scholar	https://scholar.google.com/
Bahasa Indonesia	butterfly range contraction	Penyempitan area/daerah/wilayah jangkauan kupu-kupu	Google Scholar	https://scholar.google.com/
Bahasa Indonesia	new butterfly	Jenis/spesies kupu-kupu baru	Google Scholar	https://scholar.google.com/
Bahasa Indonesia	butterfly range shift	Pergeseran daerah/wilayah/area sebaran kupu-kupu	Google Scholar	https://scholar.google.com/
Bahasa Melayu (Malay)	butterfly range change	Perubahan julat/julatan rama-rama	Google Scholar	https://scholar.google.com/
Bahasa Melayu (Malay)	butterfly range expansion	Pengembangan julat/julatan rama-rama	Google Scholar	https://scholar.google.com/
Bahasa Melayu (Malay)	butterfly distribution change	Perubahan taburan/sebaran rama-rama	Google Scholar	https://scholar.google.com/
Bahasa Melayu (Malay)	butterfly invasion	Pencerobohan (spesies) rama-rama	Google Scholar	https://scholar.google.com/

Bahasa Melayu (Malay)	butterfly range contraction	Penyempitan/pengecutan julat/julatan rama-rama	Google Scholar	https://scholar.google.com/
Bahasa Melayu (Malay)	new butterfly	(Spesies) Rama-rama baharu	Google Scholar	https://scholar.google.com/
Bahasa Melayu (Malay)	butterfly range shift	Peralihan julat/julatan rama-rama	Google Scholar	https://scholar.google.com/
Chinese (Simplified)	butterfly range change	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 变迁/变化 (change)	CNKI	https://cnki.net/
Chinese (Simplified)	butterfly range expansion	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 扩张 (expand)	CNKI	https://cnki.net/
Chinese (Simplified)	butterfly distribution change	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 变迁/变化 (change)	CNKI	https://cnki.net/
Chinese (Simplified)	butterfly invasion	蝶类/蝴蝶 (butterfly species/butterfly) 入侵 (invasion)	CNKI	https://cnki.net/
Chinese (Simplified)	butterfly range contraction	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 减/退缩 (contract/reduce)	CNKI	https://cnki.net/
Chinese (Simplified)	new butterfly	蝶类/蝴蝶 (butterfly species/butterfly)	CNKI	https://cnki.net/

		新种 (new species) 新纪录 (new records)		
Chinese (Simplified)	butterfly range shift	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 变迁/变化 (change)	CNKI	https://cnki.net/
Chinese (Simplified)	butterfly range change	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 变迁/变化 (change)	Google Scholar	https://scholar.google.com/
Chinese (Simplified)	butterfly range expansion	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 扩张 (expand)	Google Scholar	https://scholar.google.com/
Chinese (Simplified)	butterfly distribution change	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 变迁/变化 (change)	Google Scholar	https://scholar.google.com/
Chinese (Simplified)	butterfly invasion	蝶类/蝴蝶 (butterfly species/butterfly) 入侵 (invasion)	Google Scholar	https://scholar.google.com/
Chinese (Simplified)	butterfly range contraction	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 缩减/退缩 (contract/reduce)	Google Scholar	https://scholar.google.com/
Chinese (Simplified)	new butterfly	蝶类/蝴蝶 (butterfly species/butterfly)	Google Scholar	https://scholar.google.com/

		新种 (new species) 新纪录 (new records)		
Chinese (Simplified)	butterfly range shift	蝶类/蝴蝶 (butterfly species/butterfly) 分布 (range) 变迁/变化 (change)	Google Scholar	https://scholar.google.com/
Chinese (Traditional)	butterfly range change	蝶類/蝴蝶 分布變遷/變化	Airiti Library	https://www.airitilibrary.com/
Chinese (Traditional)	butterfly range expansion	蝶類/蝴蝶 分布擴張	Airiti Library	https://www.airitilibrary.com/
Chinese (Traditional)	butterfly distribution change	蝶類/蝴蝶 分布變遷/變化	Airiti Library	https://www.airitilibrary.com/
Chinese (Traditional)	butterfly invasion	蝶類/蝴蝶 入侵	Airiti Library	https://www.airitilibrary.com/
Chinese (Traditional)	butterfly range contraction	蝶類/蝴蝶 分布縮減/退縮	Airiti Library	https://www.airitilibrary.com/
Chinese (Traditional)	butterfly range shift	蝶類/蝴蝶 分布變遷/變化	Airiti Library	https://www.airitilibrary.com/
Chinese (Traditional)	new butterfly	新種/新紀錄 蝶類/蝴蝶	Airiti Library	https://www.airitilibrary.com/
Chinese (Traditional)	butterfly range change	蝶類/蝴蝶 分布變遷/變化	Google Scholar	https://scholar.google.com/
Chinese (Traditional)	butterfly range expansion	蝶類/蝴蝶 分布變遷/變化	Google Scholar	https://scholar.google.com/
Chinese (Traditional)	butterfly distribution change	蝶類/蝴蝶 分布變遷/變化	Google Scholar	https://scholar.google.com/

Chinese (Traditional)	butterfly invasion	蝶類/蝴蝶 入侵	Google Scholar	https://scholar.google.com/
Chinese (Traditional)	butterfly range contraction	蝶類/蝴蝶 分布縮減/退縮	Google Scholar	https://scholar.google.com/
Chinese (Traditional)	new butterfly	新種/新紀錄 蝶類/蝴蝶	Google Scholar	https://scholar.google.com/
Chinese (Traditional)	butterfly range shift	蝶類/蝴蝶 分布變遷/變化	Google Scholar	https://scholar.google.com/
English	butterfly range change	NA	Google Scholar	https://scholar.google.com/
English	butterfly range expansion	NA	Google Scholar	https://scholar.google.com/
English	butterfly distribution change	NA	Google Scholar	https://scholar.google.com/
English	butterfly invasion	NA	Google Scholar	https://scholar.google.com/
English	butterfly range contraction	NA	Google Scholar	https://scholar.google.com/
English	new butterfly	NA	Google Scholar	https://scholar.google.com/
English	butterfly range shift	NA	Google Scholar	https://scholar.google.com/
English	TS= ((butterfl* OR "Rhopalocera" OR "Papilionoid*" OR "Nymphalid*" OR	NA	Web of Science Core Collection with all databases	https://www.webofscience.com/wos/woscc/basic-search

	"Papilionid*" OR "Lycaenid*" OR "Hesperiid*" OR "Pierid*" OR "Riodinid*") AND ("range" OR "shift" OR expan* OR contract* OR "distribution" OR "invasion" OR "new butterfly"))			
French	butterfly range change	changement d'aire géographique du papillon	Persee	https://www.persee.fr/
French	butterfly range expansion	expansion de l'aire géographique du papillon	Persee	https://www.persee.fr/
French	butterfly distribution change	changement de distribution du papillon	Persee	https://www.persee.fr/
French	butterfly invasion	invasion du papillon	Persee	https://www.persee.fr/
French	butterfly range contraction	diminution de l'aire géographique du papillon	Persee	https://www.persee.fr/
French	butterfly range shift	déplacement de l'aire géographique du papillon	Persee	https://www.persee.fr/
French	new butterfly	nouveau papillon	Persee	https://www.persee.fr/

French	butterfly range change	changement d'aire géographique du papillon	Google Scholar	https://scholar.google.com/
French	butterfly range expansion	expansion de l'aire géographique du papillon	Google Scholar	https://scholar.google.com/
French	butterfly distribution change	changement de distribution du papillon	Google Scholar	https://scholar.google.com/
French	butterfly invasion	invasion du papillon	Google Scholar	https://scholar.google.com/
French	butterfly range contraction	diminution de l'aire géographique du papillon	Google Scholar	https://scholar.google.com/
French	new butterfly	nouveau papillon	Google Scholar	https://scholar.google.com/
French	butterfly range shift	déplacement de l'aire géographique du papillon	Google Scholar	https://scholar.google.com/
German	butterfly range change	Veränderung Verbreitungsgebiet/~~Areal~~ Schmetterling	BASE	https://de.base-search.net/
German	butterfly range expansion	Ausbreitung/~~Expansion~~ Verbreitungsgebiet/~~Areal~~ Schmetterling	BASE	https://de.base-search.net/
German	butterfly distribution change	Veränderung Verbreitung Schmetterling	BASE	https://de.base-search.net/
German	butterfly invasion	Invasion Schmetterling	BASE	https://de.base-search.net/
German	butterfly range contraction	Verkleinerung ~~Areal~~/Verbreitungsgebiet Schmetterling	BASE	https://de.base-search.net/

German	butterfly range shift	Verschiebung Verbreitungsgebiet/Areal Schmetterling	BASE	https://de.base-search.net/
German	new butterfly	neuer Schmetterling	BASE	https://de.base-search.net/
German	butterfly range change	Veränderung Verbreitungsgebiet/~~Areal~~ Schmetterling	Google Scholar	https://scholar.google.com/
German	butterfly range expansion	Ausbreitung/~~Expansion~~ Verbreitungsgebiet/~~Areal~~ Schmetterling	Google Scholar	https://scholar.google.com/
German	butterfly distribution change	Veränderung Verbreitung Schmetterling	Google Scholar	https://scholar.google.com/
German	butterfly invasion	Invasion Schmetterling	Google Scholar	https://scholar.google.com/
German	butterfly range contraction	Verkleinerung Areal/Verbreitungsgebiet Schmetterling	Google Scholar	https://scholar.google.com/
German	butterfly range shift	Verschiebung Verbreitungsgebiet/~~Areal~~ Schmetterling	Google Scholar	https://scholar.google.com/
German	new butterfly	neuer Schmetterling	Google Scholar	https://scholar.google.com/
Hebrew	butterfly range change	שינוי תפוצה פרפר	Google Scholar	https://scholar.google.com/
Hebrew	butterfly range expansion	הרחבת תחום תפוצה פרפרים	Google Scholar	https://scholar.google.com/
Hebrew	butterfly distribution change	שינוי תחום תפוצה פרפרים	Google Scholar	https://scholar.google.com/

Hebrew	butterfly invasion	פרפר מינים פולשים	Google Scholar	https://scholar.google.com/
Hebrew	butterfly range contraction	פרפר תפוצה צמצום	Google Scholar	https://scholar.google.com/
Hebrew	new butterfly	פרפר חדש ישראל	Google Scholar	https://scholar.google.com/
Hebrew	butterfly range shift	שינויי תפוצה פרפרים	Google Scholar	https://scholar.google.com/
Japanese	butterfly range change	蝶　範囲変化	J-Stage	https://www.jstage.jst.go.jp/browse/-char/en
Japanese	butterfly range expansion	蝶　範囲拡大	J-Stage	https://www.jstage.jst.go.jp/browse/-char/en
Japanese	butterfly distribution change	蝶　分布変化	J-Stage	https://www.jstage.jst.go.jp/browse/-char/en
Japanese	butterfly invasion	蝶　侵入	J-Stage	https://www.jstage.jst.go.jp/browse/-char/en
Japanese	butterfly range contraction	蝶　範囲縮小	J-Stage	https://www.jstage.jst.go.jp/browse/-char/en
Japanese	butterfly range shift	蝶　範囲移動	J-Stage	https://www.jstage.jst.go.jp/browse/-char/en
Japanese	new butterfly	蝶　新記載	J-Stage	https://www.jstage.jst.go.jp/browse/-char/en
Japanese	butterfly range change	蝶　範囲変化	Google Scholar	https://scholar.google.com/
Japanese	butterfly range expansion	蝶　範囲拡大	Google Scholar	https://scholar.google.com/
Japanese	butterfly distribution change	蝶　分布変化	Google Scholar	https://scholar.google.com/

Japanese	butterfly invasion	蝶　侵入	Google Scholar	https://scholar.google.com/
Japanese	butterfly range contraction	蝶　範囲縮小	Google Scholar	https://scholar.google.com/
Japanese	new butterfly	蝶　新記載	Google Scholar	https://scholar.google.com/
Japanese	butterfly range shift	蝶　範囲移動	Google Scholar	https://scholar.google.com/
Korean	butterfly range change	나비 범위 변화	KCI	https://www.kci.go.kr/kciportal/main.kci?locale=en
Korean	butterfly range expansion	나비 범위 확장, 나비 범위 확대, 나비 범위 증가	KCI	https://www.kci.go.kr/kciportal/main.kci?locale=en
Korean	butterfly distribution change	나비 분포 변화, 나비 분포 변동	KCI	https://www.kci.go.kr/kciportal/main.kci?locale=en
Korean	butterfly invasion	나비 침입, 나비 외래	KCI	https://www.kci.go.kr/kciportal/main.kci?locale=en
Korean	butterfly range contraction	나비 범위 쇠퇴, 나비 범위 축소, 나비 범위 감소	KCI	https://www.kci.go.kr/kciportal/main.kci?locale=en
Korean	butterfly range shift	나비 범위 변동, 나비 범위 변화	KCI	https://www.kci.go.kr/kciportal/main.kci?locale=en
Korean	new butterfly	신종 나비, 미기록 나비	KCI	https://www.kci.go.kr/kciportal/main.kci?locale=en
Korean	butterfly range change	나비 범위 변화	Google Scholar	https://scholar.google.com/
Korean	butterfly range expansion	나비 범위 확장, 나비 범위 확대, 나비 범위 증가	Google Scholar	https://scholar.google.com/

Korean	butterfly distribution change	나비 분포 변화, 나비 분포 변동	Google Scholar	https://scholar.google.com/
Korean	butterfly invasion	나비 침입, 나비 외래	Google Scholar	https://scholar.google.com/
Korean	butterfly range contraction	나비 범위 쇠퇴, 나비 범위 축소, 나비 범위 감소	Google Scholar	https://scholar.google.com/
Korean	new butterfly	나비 범위 변동, 나비 범위 변화	Google Scholar	https://scholar.google.com/
Korean	butterfly range shift	신종 나비, 미기록 나비	Google Scholar	https://scholar.google.com/
Persian	butterfly range change	تغییر محدوده پروانه	SID	https://www.sid.ir/
Persian	butterfly range expansion	گسترش محدوده پروانه	SID	https://www.sid.ir/
Persian	butterfly distribution change	تغییر توزیع پروانه	SID	https://www.sid.ir/
Persian	butterfly invasion	هجوم پروانه	SID	https://www.sid.ir/
Persian	butterfly range contraction	کوچک شدن محدوده پروانه	SID	https://www.sid.ir/
Persian	butterfly range shift	جابجایی محدوده پروانه	SID	https://www.sid.ir/
Persian	new butterfly	پروانه جدید	SID	https://www.sid.ir/
Persian	butterfly range change	تغییر محدوده پروانه	Google Scholar	https://scholar.google.com/

Persian	butterfly range expansion	گسترش محدوده پروانه	Google Scholar	https://scholar.google.com/
Persian	butterfly distribution change	تغییر توزیع پروانه	Google Scholar	https://scholar.google.com/
Persian	butterfly invasion	هجوم پروانه	Google Scholar	https://scholar.google.com/
Persian	butterfly range contraction	کوچک شدن محدوده پروانه	Google Scholar	https://scholar.google.com/
Persian	new butterfly	پروانه جدید	Google Scholar	https://scholar.google.com/
Persian	butterfly range shift	جابجایی محدوده پروانه	Google Scholar	https://scholar.google.com/
Polish	butterfly range change	zmiana zasięgu występowania motyli	Polska Bibliografia Naukowa	https://pbn.nauka.gov.pl/core/#/home
Polish	butterfly range expansion	rozszerzenie zasięgu występowania motyli	Polska Bibliografia Naukowa	https://pbn.nauka.gov.pl/core/#/home
Polish	butterfly distribution change	zmiana rozmieszczenia motyli	Polska Bibliografia Naukowa	https://pbn.nauka.gov.pl/core/#/home
Polish	butterfly invasion	inwazyjne gatunki motyli	Polska Bibliografia Naukowa	https://pbn.nauka.gov.pl/core/#/home
Polish	butterfly range contraction	zmiejszenie zasięgu występowania motyli	Polska Bibliografia Naukowa	https://pbn.nauka.gov.pl/core/#/home

Polish	butterfly range shift	przesunięcie zasięgu występowania motyli	Polska Bibliografia Naukowa	https://pbn.nauka.gov.pl/core/#/home
Polish	new butterfly	nowy gatunek motyla	Polska Bibliografia Naukowa	https://pbn.nauka.gov.pl/core/#/home
Polish	butterfly range change	zmiana zasięgu występowania motyli	Google Scholar	https://scholar.google.com/
Polish	butterfly range expansion	rozszerzenie zasięgu występowania motyli	Google Scholar	https://scholar.google.com/
Polish	butterfly distribution change	zmiana rozmieszczenia motyli	Google Scholar	https://scholar.google.com/
Polish	butterfly invasion	inwazyjne gatunki motyli	Google Scholar	https://scholar.google.com/
Polish	butterfly range contraction	zmiejszenie zasięgu występowania motyli	Google Scholar	https://scholar.google.com/
Polish	new butterfly	nowy gatunek motyla	Google Scholar	https://scholar.google.com/
Polish	butterfly range shift	przesunięcie zasięgu występowania motyli	Google Scholar	https://scholar.google.com/
Portuguese	butterfly range change	mudança na área de ocupação de Lepidoptera	SciELO	https://scielo.org/en
Portuguese	butterfly range expansion	expansão na área de ocupação de Lepidoptera	SciELO	https://scielo.org/en
Portuguese	butterfly distribution change	mudança de distribuição	SciELO	https://scielo.org/en

		geográfica de Lepidoptera		
Portuguese	butterfly invasion	invasão por Lepidoptera	SciELO	https://scielo.org/en
Portuguese	butterfly range contraction	redução da área de ocupação de Lepidoptera	SciELO	https://scielo.org/en
Portuguese	butterfly range shift	alteração da área de ocupação de Lepidoptera	SciELO	https://scielo.org/en
Portuguese	new butterfly	nova Lepidoptera	SciELO	https://scielo.org/en
Portuguese	butterfly range change	mudança na área de ocupação de Lepidoptera	Google Scholar	https://scholar.google.com/
Portuguese	butterfly range expansion	expansão na área de ocupação de Lepidoptera	Google Scholar	https://scholar.google.com/
Portuguese	butterfly distribution change	mudança de distribuição geográfica de Lepidoptera	Google Scholar	https://scholar.google.com/
Portuguese	butterfly invasion	invasão por Lepidoptera	Google Scholar	https://scholar.google.com/
Portuguese	butterfly range contraction	redução da área de ocupação de Lepidoptera	Google Scholar	https://scholar.google.com/
Portuguese	new butterfly	nova Lepidoptera	Google Scholar	https://scholar.google.com/
Portuguese	butterfly range shift	alteração da área de ocupação de Lepidoptera	Google Scholar	https://scholar.google.com/
Spanish	butterfly range change	Cambio en el rango de distribución de mariposas	SciELO	https://scielo.org/en

Spanish	butterfly range expansion	Expansión en el rango de distribución de mariposas	SciELO	https://scielo.org/en
Spanish	butterfly distributio n change	Cambio en el rango de distribución de mariposas	SciELO	https://scielo.org/en
Spanish	butterfly invasion	Invasión de mariposas	SciELO	https://scielo.org/en
Spanish	butterfly range contractio n	Contracción/reduc ción en el rango de distribución de mariposas	SciELO	https://scielo.org/en
Spanish	butterfly range shift	Cambio en el rango de distribución de mariposas	SciELO	https://scielo.org/en
Spanish	new butterfly	Nueva especie de mariposa	SciELO	https://scielo.org/en
Spanish	butterfly range change	Cambio en el rango de distribución de mariposas	Google Scholar	https://scholar.google.com/
Spanish	butterfly range expansion	Expansión en el rango de distribución de mariposas	Google Scholar	https://scholar.google.com/
Spanish	butterfly distributio n change	Cambio en el rango de distribución de mariposas	Google Scholar	https://scholar.google.com/
Spanish	butterfly invasion	Invasión de mariposas	Google Scholar	https://scholar.google.com/
Spanish	butterfly range contractio n	Contracción/reduc ción en el rango de distribución de mariposas	Google Scholar	https://scholar.google.com/
Spanish	new butterfly	Cambio en el rango de	Google Scholar	https://scholar.google.com/

		distribución de mariposas		
Spanish	butterfly range shift	Nueva especie de mariposa	Google Scholar	https://scholar.google.com/
Swedish	butterfly range change	förändring av fjärilars utbredningsområde	Google Scholar	https://scholar.google.com/
Swedish	butterfly range expansion	expansion av fjärilars utbredningsområde	Google Scholar	https://scholar.google.com/
Swedish	butterfly distribution change	förändring av fjärilars spridning	Google Scholar	https://scholar.google.com/
Swedish	butterfly invasion	invasion av fjärilar	Google Scholar	https://scholar.google.com/
Swedish	butterfly range contraction	minskning av fjärilars utbredningsområde	Google Scholar	https://scholar.google.com/
Swedish	new butterfly	ny fjäril	Google Scholar	https://scholar.google.com/
Swedish	butterfly range shift	skifte i fjärilars utbredningsområde	Google Scholar	https://scholar.google.com/