Minimising Risks of Global Change by Enhancing Resilience of Pollinators in Agricultural Systems: Drivers, Risks, and Societal Responses

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17 Minimising Risks of Global Change by Enhancing Resilience of Pollinators in Agricultural Systems

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17.1 Importance of Pollinators

Pollination of wild and crop plants by animal pollinators is a key ecosystem service that is important to human welfare. However, the societal benefits and dependencies of pollination vary in different times and places (*see* Chap. 16). About 90% of wild plant species depend at least partially on animal pollination [1] and about 70% of the most important global crops rely to some extent on animal pollination [2]. These crops constitute 35% of global food production, and the worldwide economic value of pollination is estimated to amount to €153 billion per year [3]. In addition, most essential nutrients in human diets, like vitamin C, are provided by plants that depend entirely or substantially on pollinators [4].

Although pollinators belong to many different animal groups, insects are usually considered to be the most important pollinators [5]. Managed pollinators, such as honeybees or some bumblebees, might be less sensitive to threats of global change. It has been shown, however, that wild bees make a critical contribution to the yield of crops and are usually more efficient than managed pollinators in agricultural landscapes [6].

Which ecosystem services are addressed? Pollination

What is the research question addressed? How does climate change impact pollinators, and can land management be used to increase their resilience?

Which method has been applied? Analysing observed range shifts; species distribution models and future scenario projections; generalised linear mixed effects modelling of monitoring data

What is the main result? Current climate change has already led to range contractions of pollinators, while it is projected to have an even more severe impact in the future. However, proper land management can increase resilience of pollinator communities

What is concluded, recommended? Effects of increasing the amounts of semi-natural areas are positive and twofold: they directly increase the richness and abundance of pollinators while simultaneously making them more resilient against other threats of global change such as climate warming. However, the intended level of 7% of Ecological Focus Areas by the EU Common Agricultural Policy falls too short; at least ca. 17% are needed

17.2 Multiple Threats to Wild Pollinators

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reports current declines of wild pollinators in abundance, occurrence, and diversity [7, 8], and such declines have been attributed to multiple drivers of change. Habitat loss and degradation along with intensive agricultural practices are among the most important factors, but climate change, spread of diseases, and alien species are also impacting pollinators [9]. Most importantly, these drivers do not act in isolation but may interact to reinforce, or alternatively to weaken, the response of wild pollinators to a particular driver depending on the severity of another one [10, 11]. Such interactive effects could also be leveraged to increase the resilience of pollinator communities. Here, we highlight how climate change can impact pollinators and how new land management practices can increase the resilience of local wild bee communities to the impacts of global warming.

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17.3 Impact of Climate Change on the Distribution of Pollinators

17.3.1 Current Climate Change

The Intergovernmental Panel on Climate Change (IPCC) reports that climate change has already caused shifts in the range of many species groups [12, 13]. For most taxa, range expansions towards the poles are a common response to warming [14], while range contractions at the equatorward range margins are rare [15]. Bumblebees, however, one of the most important pollinator groups, show the opposite pattern: Climate warming relates to severe range contractions in the south, while species generally have not expanded northwards (Fig. 17.1) [16].

These alarming results were revealed by a comprehensive cross-continental study in which we tracked long-term observations (110 years) across Europe and North America on a database of approximately 423,000 georeferenced observations of 67 bumblebee species. On this basis, we tested for climate change-related range shifts in bumblebee species across the full extents of their latitudinal and thermal limits. We found cross-continentally consistent range losses from southern range limits while, most of the species failed to track climate warming at their northern margins (Fig. 17.2).

17.3.2 Future Climate Change

For pollinators as important as bumblebees, the strong retractions at the equatorward range margins, combined with their failure to track climate warming with northwards range expansions, have implications for species distribution as climate change proceeds. For example, assessments of climate change risks (in the sense of impacting ecosystem state and condition; *see* Chap. 1) make assumptions about species' ability to track changing climates. When our findings are

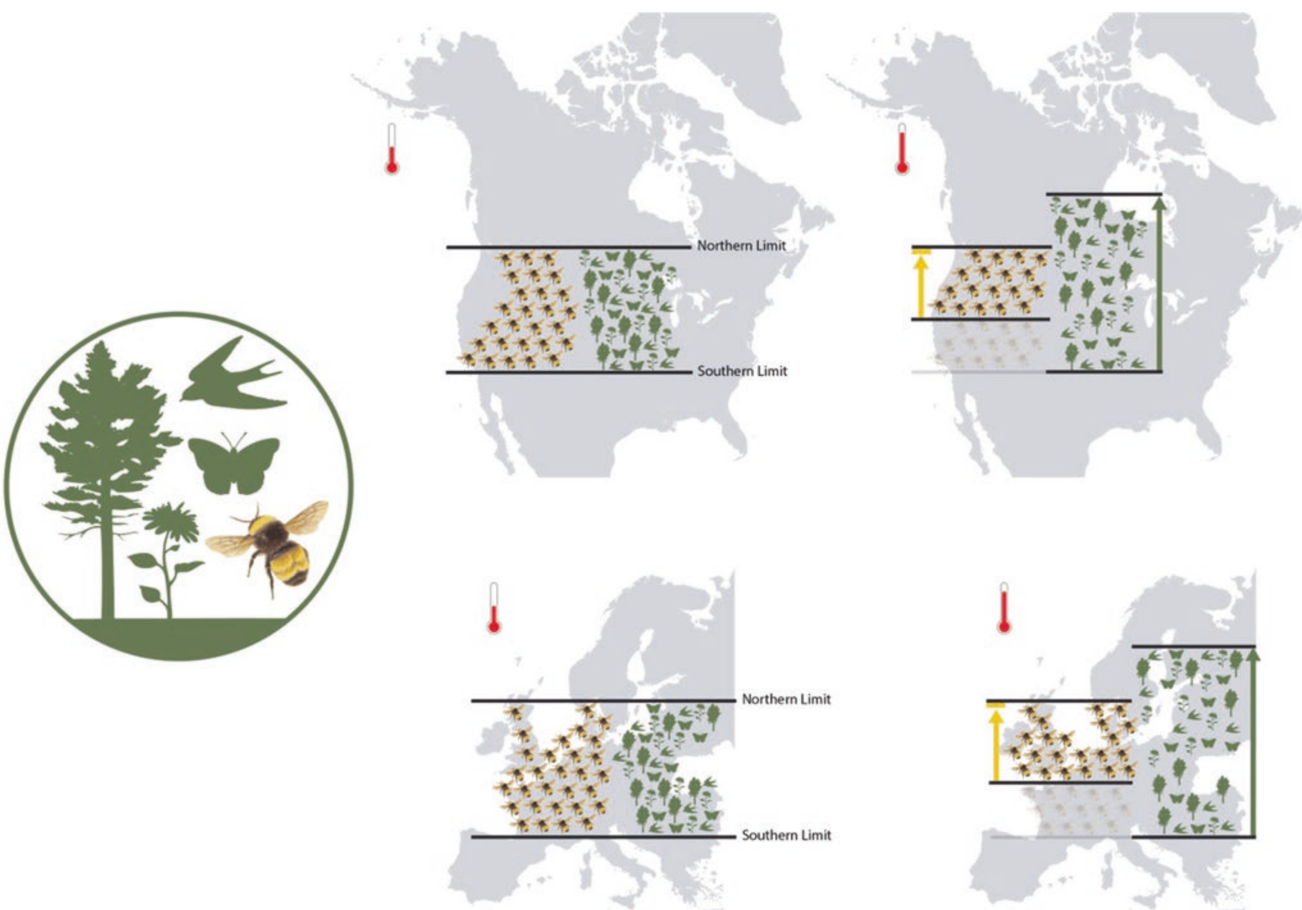

Fig. 17.1 Schematic comparison of observed responses of different species groups to climate warming in North America and Europe. While the majority of species groups (green symbols) respond to climate warming primarily with poleward range expansions and with minimal response at the equatorward margins, bumblebees (yellow symbols) react with strong range contractions at the equatorward margin but fail to expand polewards. *Image courtesy of* Ann Sanderson

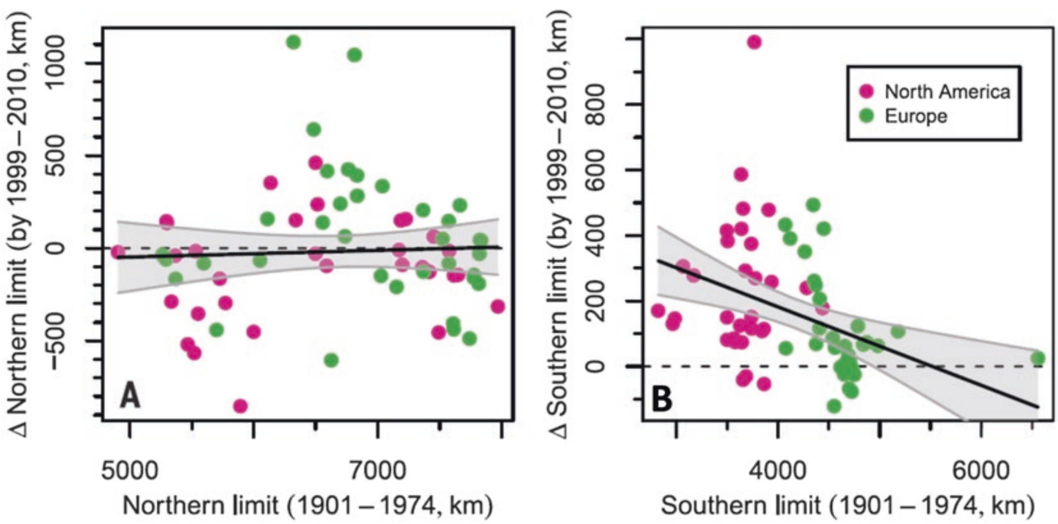

Fig. 17.2 Climate change responses of 67 bumblebee species across full latitudinal limits in Europe and North America. The y-axis shows changes in latitudinal range limits at the northern (**a**) and southern (**b**) range margin between the historical (1901–1974) and the current (1999–2010) distribution of bumblebee species. (**a**) Positive values indicate range expansions from species' historical northern limits. (**b**) Positive values indicate range losses from species' southern limits. The grey area indicates 95% confidence bands for regression models of observed changes in range limits vs. historical range limits (*From* Kerr et al. [16]; *with permission*)

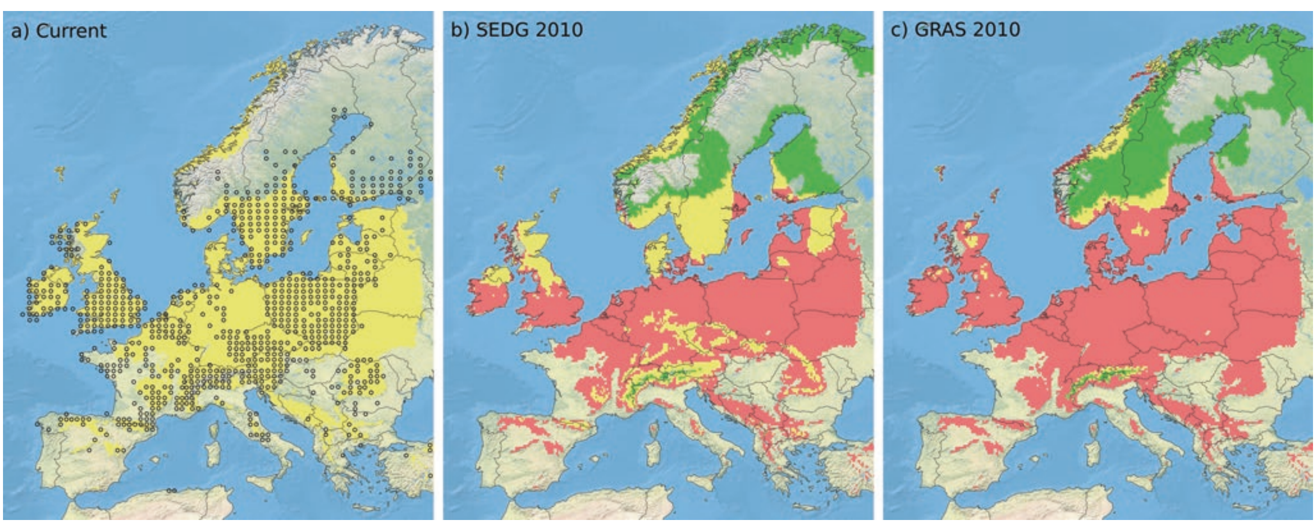

Fig. 17.3 Projected changes in suitable climatic conditions for the bumblebee *Bombus ruderarius*. (**a**) Current (open circles) and modelled (yellow area) distribution. (**b** and **c**) projected changes under 3 °C warming scenario (SEDG) and a 5.6 °C warming scenario (GRAS) for 2100. Red—losses; yellow—remaining suitable conditions; green—new areas with suitable conditions but only reachable under the assumption of full ability to track climate change (*From* Rasmont et al. [17]; *with permission*)

incorporated in such assessments, the consequences for bumblebees are severe. Based on relevant climate data and 300,435 records of all 69 European bumblebee species between 1970 and 2000, we developed species distribution models and projected the changes in suitable climatic conditions for these species under future climate change scenarios [17]. These projections relied on two alternative assumptions—full ability and no ability to track warming—leading to considerable differences when estimating future risks of climate change. Strong future retractions at the southern margins in combination with the failure to keep track with climate warming at the northern margins suggest a grim fate for many bumblebees (Fig. 17.3). Comparing full ability vs. no ability to track climate change, the proportion of bumblebee species losing more than 70% of climatically suitable area increased from 5% to 18%, 18% to 56%, or 65% to 95% under warming scenarios of 3.0 °C, 4.7 °C, and 5.6 °C, respectively, by the year 2100 (Fig. 17.4).

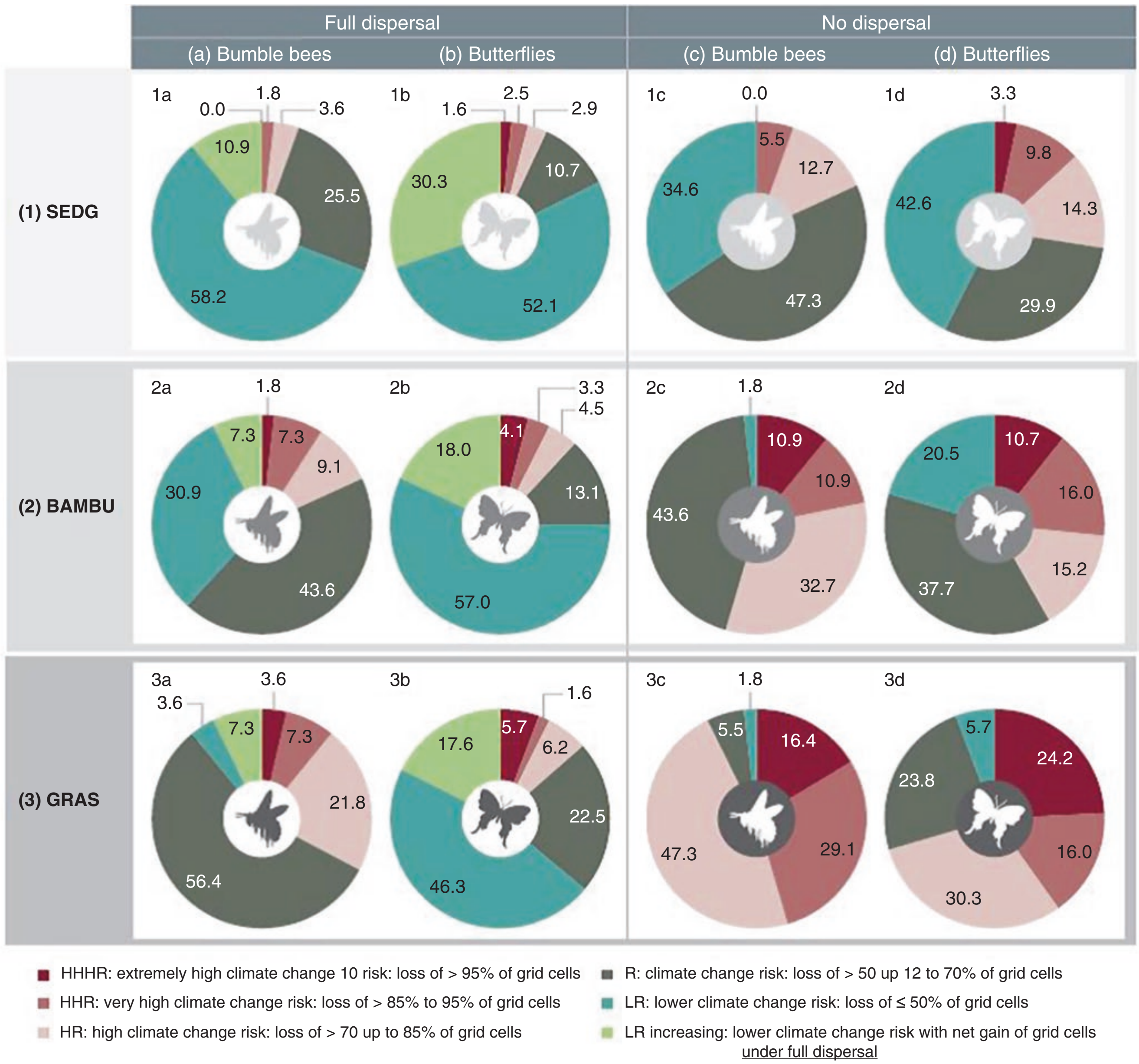

Fig. 17.4 Projected risks for European bumblebees and butterflies under different scenarios of climate change, assuming full (left) or no (right) dispersal. Risk corresponds to impacts on ecosystem state and condition following the framework of Chap. 1. Scenarios: SEDG, sustainable Europe development goal (equivalent to the IPCC B1 scenario with a mean expected temperature increase of 3.0 ° C in Europe by 2100); BAMBU, business-as-might-be-usual (equivalent to the IPCC A2 scenario with an expected temperature increase of 4.7 °C in Europe by 2100); and GRAS, growth applied strategy (equivalent to the IPCC A1FI climate change scenario with a mean expected temperature increase of 5.6 °C in Europe by 2100) (*From* IPBES [8]; *with permission*)

17.4 Land Management Can Increase Resilience of Pollinator Communities in Agricultural Landscapes

Sound management strategies are needed to minimise risks of climate change for pollinators and pollination services. To compensate for potential failures to track changing climates at the poleward range margins, managed relocation may be necessary [16], but only after careful study of risks and benefits of such actions [18].

In addition to management actions at the northern range margins, increasing resilience of pollinator populations at the southern range margins is also required. We conducted a study based on data using 95 local wild bee communities collected over three years at six intervals of two weeks in six agricultural landscapes differing in the amount of agri-

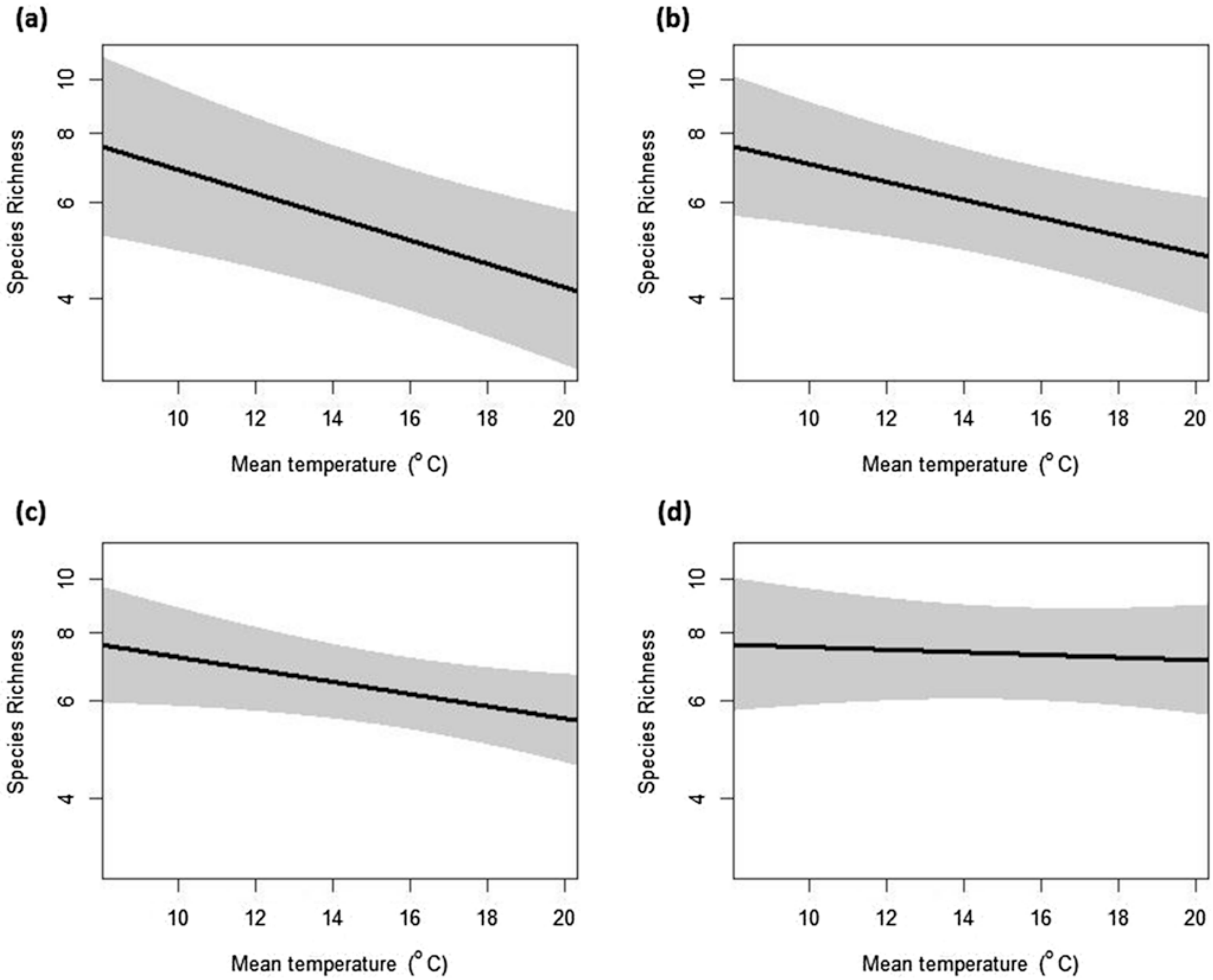

Fig. 17.5 Interactive effect of temperature and amount of semi-natural habitat on bee species richness. The effect of temperature increase on species richness is displayed for four different levels of percentage of semi-natural areas covering the entire range of the six study sites: (**a**) 2%; (**b**) 6%; (**c**) 10%; (**d**) 17%. Grey bands indicate 95% confidence intervals (*From* Papanikolaou et al. [20]; *with permission*)

cultural and semi-natural habitats. Study sites were located in Central Germany and are part of the TERENO project (Terrestrial Environmental Observatories; www.tereno.net) [19]. We found positive effects of semi-natural area and negative effects of warmer temperatures on both richness and abundance of bee species. More surprisingly, we found an interaction between temperature and the amount of semi-natural habitats in terms of species' survival prospects (Fig. 17.5) [20]. Translating these results of overly hot weather to increasing temperatures caused by climate change, this means that higher amounts of semi-natural habitats can effectively buffer negative effects of warming, and thus increase pollinator resilience amid changing climates.

17.5 Policy Implications

Given the importance of wild pollinators to the economy and human nutrition, it is essential to minimise risks confronting pollination services through measures that increase pollinator resilience. In combination with land-use intensification, climate change could drastically shrink the global distribution and abundance of pollinator species. However, increasing the amount of semi-natural habitats in agricultural landscapes might be an efficient instrument to enhance pollinator resilience against climate warming. The potential benefit of such an instrument is high, since large agricultural areas in Europe are characterised by extremely low amounts of semi-natural areas. For instance, in about 45% of agricul-

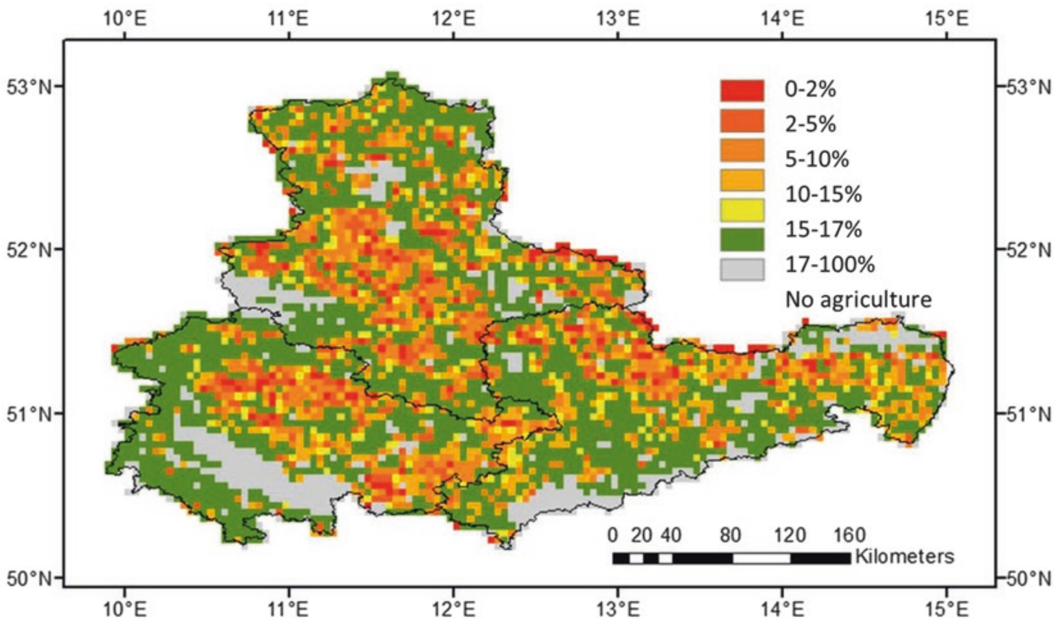

Fig. 17.6 Percentage of semi-natural area in agricultural landscapes as indicator for pollinator resilience against climate warming in Central Germany. According to findings of Papanikolaou et al. [20], a threshold of 17% of semi-natural area is assumed under which local pollinator communities are increasingly less resilient against negative effects of climate warming

tural landscapes in Central Germany, the amount of semi-natural habitat is less than 17% (Fig. 17.6), a critical threshold below which species face sharply elevated local extinction risks [20]. Although the actual numbers were assessed by a study in Central Germany, and they may vary across geographic regions, the main principle is likely to be applicable across temperate agroecosystems. The positive effects of higher amounts of semi-natural areas are twofold: they directly increase the richness and abundance of pollinators while simultaneously making them more resilient against other threats, such as global climate warming. Ensuring the resilience of pollinators under climate change is yet another reason to accelerate efforts to design agricultural landscapes for pollination services, and to implement practices that optimize the amount and distribution of semi-natural areas. In this sense, some regulations of the EU Common Agricultural Policy (CAP) and the EU strategy for Green Infrastructure point in the right direction. Article 46 of the EU Regulation 1307/2013 [21] focuses on the greening of agricultural areas by designating Ecological Focus Areas (EFA). These EFAs should cover 5% by 2015 and 7% shortly thereafter. However, the study by Papanikolaou et al. [20] indicates that this threshold falls too short for pollinators. Increasing the targets for semi-natural area to at least 17% is likely needed to increase pollinator resilience as these species confront the impacts of rapid global change.

References

1. Ollerton J, Winfree R, Tarrant S. How many flowering plants are pollinated by animals? Oikos. 2011;120(3):321–6.
2. Klein AM, Vaissiere BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, et al. Importance of pollinators in changing landscapes for world crops. Proc Roy Soc B Biol Sci. 2007;274(1608):303–13.
3. Gallai N, Salles JM, Settele J, Vaissiere BE. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecol Econ. 2009;68(3):810–21.
4. Eilers EJ, Kremen C, Greenleaf SS, Garber AK, Klein AM. Contribution of pollinator-mediated crops to nutrients in the human food supply. PLoS One. 2011;6(6):e21363.
5. Kearns CA, Inouye DW, Waser NM. Endangered mutualisms: the conservation of plant-pollinator interactions. Annu Rev Ecol Syst. 1998;29:83–112.
6. Garibaldi LA, Steffan-Dewenter I, Winfree R, Aizen MA, Bommarco R, Cunningham SA, et al. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. Science. 2013;339(6127):1608–11.
7. Biesmeijer JC, Roberts SPM, Reemer M, Ohlemüller R, Edwards M, Peeters T, et al. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science. 2006;313(5785):351–4.
8. IPBES. Summary for policymakers of the assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. In: Potts SG, Imperatriz-Fonseca VL, Ngo HT, Biesmeijer JC, Breeze TD, Dicks LV, et al., editors. 2016. https://www.actu-environnement.com/media/pdf/news-26331-synthese-ipbes-decideurs-pollinisateurs.pdf. Accessed 11 Oct 2017.

9. Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin WE. Global pollinator declines: trends, impacts and drivers. Trends Ecol Evol. 2010;25(6):345–53.
10. Gonzalez-Varo JP, Biesmeijer JC, Bommarco R, Potts SG, Schweiger O, Smith HG, et al. Combined effects of global change pressures on animal-mediated pollination. Trends Ecol Evol. 2013;28(9):524–30.
11. Schweiger O, Biesmeijer JC, Bommarco R, Hickler T, Hulme PE, Klotz S, et al. Multiple stressors on biotic interactions: how climate change and alien species interact to affect pollination. Biol Rev Camb Philos Soc. 2010;85(4):777–95.
12. Parmesan C, Yohe G. A globally coherent fingerprint of climate change impacts across natural systems. Nature. 2003;421(6918): 37–42.
13. IPCC. Summary for policymakers. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, et al., editors. Climate change 2014: impacts, adaptation, and vulnerability part A: global and sectoral aspects contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2014. p. 1–32.
14. Chen I-C, Hill JK, Ohlemüller R, Roy DB, Thomas CD. Rapid range shifts of species associated with high levels of climate warming. Science. 2011;333(6045):1024–6.
15. Sunday JM, Bates AE, Dulvy NK. Thermal tolerance and the global redistribution of animals. Nat Clim Chang. 2012;2(9):686–90.
16. Kerr JT, Pindar A, Galpern P, Packer L, Potts SG, Roberts SM, et al. Climate change impacts on bumblebees converge across continents. Science. 2015;349(6244):177–80.
17. Rasmont P, Franzén M, Lecocq T, Harpke A, Roberts S, Biesmeijer JC, et al. Climatic risk and distribution Atlas of European Bumblebees. BioRisk. 2015;10:1–236.
18. Kerr JT, Pindar A, Galpern P, Packer L, Potts SG, Roberts SM, et al. Relocation risky for bumblebee colonies—response. Science. 2015;350(6258):287.
19. Zacharias S, Bogena H, Samaniego L, Mauder M, Fuss R, Putz T, et al. A network of terrestrial environmental observatories in Germany. Vadose Zone J. 2011;10(3):955–73.
20. Papanikolaou AD, Kühn I, Frenzel M, Schweiger O. Semi-natural habitats mitigate the effects of temperature rise on wild bees. J Appl Ecol. 2017;54(2):527–36.
21. Council Regulation (EC). No 1307/2013 of the European Parliament and of the Council of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009. Off J Eur Union. 2013;L347:608–70.

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