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European monitoring of genetic diversity must expand to detect impacts of climate change

Efforts to monitor genetic diversity in populations vary greatly among European countries. The populations and species that are most likely to experience the greatest impacts of climate change are not well covered by these efforts, which suggests an urgent need for a substantial expansion in their monitoring.

The problem

Population genetic diversity is the foundational component of biological diversity and is essential for the continued adaptation of species to changing environments, to avoid inbreeding depression in populations and for ecosystem resilience. Nonetheless, genetic diversity has not been at the forefront of conservation discussions and has been addressed separately from other major conservation issues such as the effects of climate change on biological diversity. Monitoring intraspecific genetic diversity is crucial for detecting how it is affected by climate change. As these effects vary from region to region, monitoring must cover areas where effects are first expected. We set out to determine whether genetic diversity monitoring practices in Europe are positioned to detect climate impacts and eventually follow the genetic diversity that is important to species' adaptive responses.

The observations

We followed a threefold approach. We first collected information to identify where the monitoring of population genetic diversity is being conducted across Europe (38 countries and 518 candidate monitoring studies). We then determined from the literature that populations near the hot–dry limits of species' ecological distributions probably hold variation that is important for adaptation to increasingly harsh, marginal conditions caused by climate change[1–4], while being threatened by the same climate trends[5]. We mapped both these factors across a substantial portion of Europe to determine the degree to which monitoring efforts coincide with areas where climate impacts are likely to be greatest over the coming decades.

We found that monitoring efforts (based on 151 national-level monitoring studies) vary greatly among European countries, and that many countries have conducted little monitoring of genetic diversity so far (Fig. 1). We also found a strong taxonomic bias in monitoring programmes. Expectedly, this bias favoured large carnivores (Fig. 1), most of which are distributed across wide climatic conditions and are therefore less threatened by climate change than other species in Europe. By contrast, very little monitoring has been done on other relevant groups such as amphibians and trees (Fig. 1).

Variation among countries in their efforts to monitor genetic diversity does not align well with the likely impacts of climate change, as indicated by the distribution of areas in which species exhibit climatic niche marginality (that is, where they are close to the limits of their climatic tolerances).

The implications

The new Kunming-Montreal Global Biodiversity framework requires reporting on genetic diversity monitoring and conservation progress by parties of the Convention on Biological Diversity. Our study will support this by establishing a baseline of genetic diversity monitoring in Europe.

The study demonstrates that several groups of species have concentrated areas of niche marginality. Furthermore, we demonstrate that monitoring effort needs to be expanded – especially in southeastern Europe – to sample populations that are likely to be first affected by climate change, in areas where local adaptation to warm, dry climate probably occurs. The study points to locations where species can be sampled to improve coverage of the climatic gradients they occupy, but the specific populations that hold critical genetic variants for adaptation to changing climate remain to be identified.

Several conclusions follow from these findings. First, deeper knowledge of the structuring of adaptive genetic variation is required for effective conservation in the future, especially for populations that exhibit climatic niche marginality. Second, genetic monitoring needs to be increasingly international and collaborative, and greater efforts must be made to promote, finance and develop monitoring activity in areas where high climate niche marginality occurs in species of current and potential future conservation interest, both in Europe and globally. Finally, instead of focusing narrowly on flagship species such as large carnivores, monitoring efforts must be broadened to include less-charismatic species (such as amphibians, forest trees and others) that will probably experience severe impacts of climate change.

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EXPERT OPINION

"The authors address the need to monitor population genetic diversity to predict future genetic diversity changes and manage impacts of climate change on populations. They used an innovative approach to integrate data on margins of species environmental distributions across 185 species and existing monitoring programmes to identify areas and taxonomic groups that urgently require genetic monitoring. The amount of work that went into identifying and filtering monitoring projects across Europe is impressive." **Alexandra Pavlova, Monash University, Melbourne, Victoria, Australia.**

FIGURE

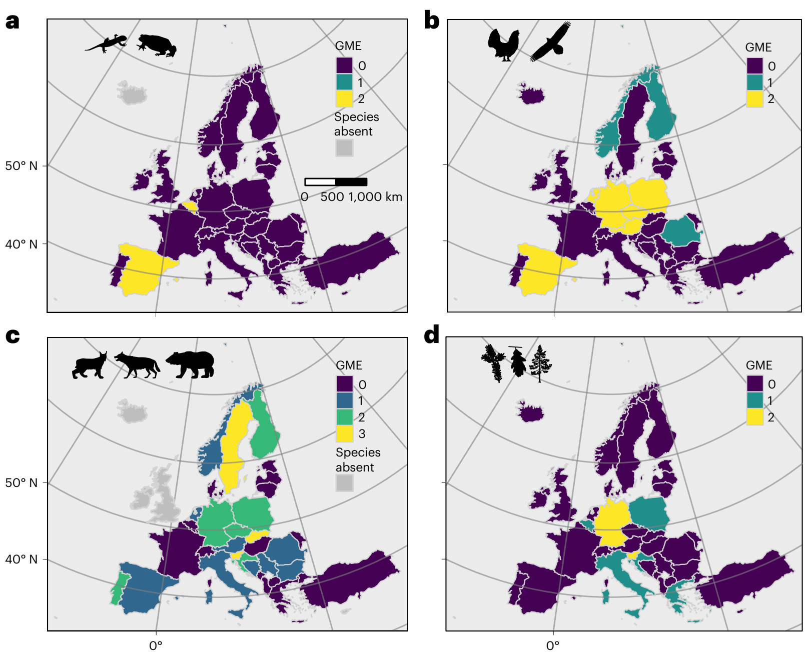

Fig. 1 | Monitoring effort as number of projects in 38 European countries. a–d, Geographical distribution of effort in the monitoring of population genetic diversity, for purposes of conservation or management, among COST (European Cooperation in Science and Technology) full-member countries, showing the tally of programmes for amphibians (**a**), birds (**b**), carnivorans (**c**) and forest trees (**d**). Programmes are consistent with category II monitoring in that they provide multiple estimates over time of at least one index of genetic diversity. Few countries have genetic monitoring effort for amphibians, whereas most countries have established at least one programme for a carnivoran species. Relatively little monitoring has been conducted in countries in southeastern Europe. GME, genetic monitoring effort.

BEHIND THE PAPER

This research was the brainchild of M. Bruford (1963–2023) and was first hatched at a meeting of the EU COST Action 'Genomic Biodiversity Knowledge for Resilient Ecosystems' (G-BiKE) in Sarajevo, Bosnia–Herzegovina, in 2019. Further development occurred in Novi Sad, Serbia, in Prague, Czech Republic, and in frequent video conferences during the COVID-19 pandemic. Outside of in-person meetings, the work was mostly unfunded. The initial focus was on determining how much monitoring of genetic diversity has been conducted in Europe. A turning point occurred when P.B.P. contacted A. Guisan to help to extend the conceptual basis of the research, to reflect on what among-country variation in monitoring effort actually implies for the conservation of genetic diversity in the face of climate change. The need to expand monitoring internationally, collaboratively and taxonomically, spanning entire climate gradients, became clear through this collaboration. **P.B.P.**

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FROM THE EDITOR

"This analysis stood out because it presented an interesting and unusual combination of different datasets by combining an evaluation of the continent-wide effort to monitor species genetic diversity with an analysis of the degree to which this diversity might enable populations of conservation concern to adapt to future climatic change. Both of these will have policy relevance for biodiversity monitoring schemes."
Editorial Team, *Nature Ecology & Evolution*.