Conservation Letters

WILEY

Conservation Letters
Open Access
A journal of the Society for Conservation Biology

LETTER OPEN ACCESS

Vulnerability and Adaptations to Climate Change in EU Protected Areas: A Natura 2000 Managers' perspective

Giorgio Zavattoni[1,2] | Jon E. Brommer[1] | Tyler Hallman[3] | Ineta Kačergytė[4] | Szabolcs Nagy[5] | Tomas Pärt[4] | Diego Pavón-Jordán[6] | Alaaeldin Soultan[7] | Yanjie Xu[8,9] | Elie Gaget[2]

[1]Department of Biology, University of Turku, Turku, Finland | [2]Tour du Valat, Research Institute for the Conservation of Mediterranean Wetlands, Arles, France | [3]School of Environmental and Natural Sciences, Bangor University, Bangor, UK | [4]Department of Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden | [5]Wetlands International European Association, Wageningen, The Netherlands | [6]Birds and Renewables Research Group, Department of Land and Biodiversity, Norwegian Institute for Nature Research, Trondheim, Norway | [7]Swiss Ornithological Institute, Sempach, Switzerland | [8]Finnish Museum of Natural History, University of Helsinki, Helsinki, Finland | [9]Finnish Environment Institute (Syke), Helsinki, Finland

Correspondence: Giorgio Zavattoni (giorgio.zavattoni@utu.fi)

Received: 2 December 2025 | **Revised:** 30 March 2026 | **Accepted:** 4 April 2026

Keywords: adaptation strategies | climate change vulnerability | EU biogeographical regions | Natura 2000 | protected area management | resist–accept–direct framework | science–management interface

ABSTRACT

The Natura 2000 (N2K)—Europe's network of protected areas—is a key conservation instrument, but its effectiveness is challenged by climate change. We surveyed 382 N2K managers to investigate their perceptions of climate change and related site adaptation strategies. Warming and precipitation shifts were frequently reported as threats, with perceived vulnerability of N2K sites highest in the Mediterranean and lowest in the Boreal region. Our results suggest that the official N2K site information stored in the Standard Data Forms greatly under-report managers' assessment of vulnerability. 58% of the surveyed managers implemented adaptation strategies, which, when characterized following a resist–accept–direct (RAD) framework, aimed not only at resisting, but also at directing and accepting the effects of climate change. Managers also highlighted several barriers to the implementation of adaptation strategies, such as lack of funding, time, stakeholders' consensus, and lack of knowledge on local vulnerability.

1 | Introduction

Anthropogenic climate change is a growing threat to biodiversity (IPBES 2019). Protected areas can support species by maintaining healthy ecosystems (Bowgen et al. 2022; Gaget et al. 2021), though mitigating climate change threats is rarely a primary management target. With the intensifying of climate change, conservation efforts need to understand and address its effects to avoid failures and waste of limited conservation resources (Greenwood et al. 2016).

To help management decisions under climate change, the resist–accept–direct (RAD) framework has been developed (Schuurman et al. 2020; Schuurman et al. 2022). The RAD framework specifies that climate change adaptation strategies can aim to: (1) resist the effects of climate change, by maintaining locally historical ecosystem condition; (2) accept the effects, by not influencing climate-imposed changes; or (3) direct the effects, by guiding the changes toward an alternative and desirable condition. For example, if a forest is degrading due to warming-driven recruitment failure of local tree species, this could be resisted by actively planting local tree species, accepted by allowing the degradation, or directed by translocating tree species adapted to warmer temperatures (Magness et al. 2022). Choosing the right strategy depends on conservation goals, and the three options can be implemented at the same site for different purposes.

The Natura 2000 (N2K) is an extensive network of protected areas across the European Union (EU), and each site has clearly defined conservation targets (Kati et al. 2015). However, there is uncertainty about the effectiveness of this network under climate change (Araújo et al. 2011), with many N2K sites projected to experience new climatic conditions (Nila et al. 2019). Around one third of N2K managers in forest ecosystems in Belgium accounted for climate change in their work (Sousa-Silva et al. 2016) while in France, the Natur'Adapt project (LIFE17 CCA/FR/000089), found that only 15% of the managers did so (EC 2025).

However, to our knowledge, no large-scale studies have investigated how managers perceive biodiversity vulnerability to climate change across Europe, which climatic drivers they feel threaten biodiversity (e.g., warming, precipitation shifts), how they adapt management practices accordingly, and what challenges they face in doing so. To fill this gap, we conducted a pan-European survey targeting N2K managers, assessing their perception of site vulnerability to climate change, the adaptation strategies they have implemented, and the challenges they encountered while implementing them. We investigate how different aspects of climate change are currently perceived as threats and compare these data to the latest official information reported to the European Commission (EC) through the Standard Data Forms (SDF). We hypothesize that managers' perception of vulnerability differs across biogeographical regions and that managers perceiving higher vulnerability will be more likely to implement adaptation strategies, as recognizing vulnerability is a critical step prior to taking action. Following the RAD framework, we expect that implemented climate change-adaptation strategies have primarily aimed to resist the effects of climate change due to the traditional stationary-based approach to conservation (Milly et al. 2008). Our results provide insights on implemented strategies for climate change-adaptations at the EU scale and help to identify barriers for their applications.

2 | Methods

2.1 | The Survey

We built an online survey to understand how N2K managers perceive and address climate change (Appendices S1 and S2). Managers selected one N2K site under their supervision and were asked to assess its vulnerability to multiple aspects of climate change, and to categorize management actions at the site within the RAD framework. Although a brief explanation of the framework was provided, responses reflect managers' perceptions and how managers categorized management actions was not separately assessed (Table 1; Appendix S2). Multiple answers from the same site (21 instances) were considered separately.

We downloaded biogeographical region borders (EEA 2025) to investigate if respondents' answers spatially differed. Sites under multiple regions were assigned to the terrestrial region with the highest coverage. One site located within the Marine Macaronesian region was excluded. Three sites under two regions without reported coverage were considered for both. The Steppic and Black Sea regions were merged due to their small size and proximity.

We downloaded the latest official site-level threat information (EEA 2021) to compare the vulnerability reported through the survey and the information in the SDFs. One site was considered vulnerable to climate change according to the managers if at least one of the four investigated climate aspects (warming, precipitation changes, extreme events, sea level rise) was perceived as a threat. Similarly, a site was considered vulnerable according to the SDF if at least one threat was reported under the category "Climate change."

2.2 | Statistical Analysis

We used a generalized linear mixed model (GLMM) to test the probability of a site being perceived as vulnerable to the four aspects of climate change (warming, precipitation changes, extreme events, sea level rise). We used the type of climate change aspect as predictor and their reported vulnerability as binary response. Since every N2K site had one row for each of the four climate change aspects, the site was included as random effect.

We tested for biogeographical region variations on the vulnerability to warming, precipitation changes, extreme events, and overall vulnerability to climate change (i.e., vulnerability to at least one of the three aspects) by running a generalized linear model (GLM, binomial) for each of them (4 models), with biogeographical regions as predictors. We excluded sea level rise due to uneven coastal sites distributions between regions and answers from the Pannonian region (11) due to model convergence issues.

To assess if perceived vulnerability to climate change motivated the implementation of adaptation strategies, we fitted three binomial GLMs. In each GLM, overall vulnerability was the predictor and the three responses were the answers to the question about adaptation strategies: (1) implemented (yes/no); (2) not implemented (yes/no); and (3) implementation uncertain (yes/no).

To examine differences in the implementation of RAD approaches, we fitted a binomial GLMM. We used the approach type (resist, accept, or direct) as predictor and their implementation (yes/no) as response. Since each N2K site was repeated 3 times (one for each approach), the site was included as random effect. Similarly, we tested if the frequency of implementation barriers differed. These two analyses were restricted to sites where adaptation strategies were reported.

All analyses were performed using R.4.2.1 (R Core Team 2022). The models were fitted with the "sdmTMB" package correcting for spatial autocorrelation through a Gaussian random field with a cutoff distance of 0.1° (Anderson et al. 2024). The absence of spatial autocorrelation was validated with a Moran's I test with threshold value of $p = 0.05$ ("DHARMa" package; Hartig 2022). p-values were calculated based on a Welsh test and pairwise comparisons extracted with the "emmeans" package (Lenth 2023).

TABLE 1 | Questions of the survey section containing climate-change-related topics.

Category	Question	Possible answers
1. Vulnerability	Do you think the increase in temperature is a threat for species/habitats targeted in this protected area?	"Yes," "No," "Probably in the future"
	Do you think the change in the frequency of precipitations is a threat for species/habitats targeted in this protected area?	"Yes," "No," "Probably in the future"
	Do you think sea level rise is a threat for species/habitats targeted in this site?	"Yes," "No," "Probably in the future"
	Do you think the increased frequency of climatic extreme events is a threat for species/habitats targeted in this protected area?	"Yes," "No," "Probably in the future"
2. Adaptations	Do you consider the impact of climate change in the management of the Natura 2000 site?	"Yes," "No," "I do not know"
3. RAD (Considered only if the answer to 2. was "Yes"; preceded by a brief explanation of the RAD framework)	Which action(s), if any, have been done in the site to RESIST the effects of climate change?	List of previously selected actions that are being implemented at the site
	Which action(s), if any, have been done in the site to ACCEPT the effects of climate change?	List of previously selected actions that are being implemented at the site
	Which action(s), if any, have been done in the site to DIRECT the effects of climate change?	List of previously selected actions that are being implemented at the site
4. Implementation barriers (Considered only if the answer to 2. was "Yes")	Is there something preventing you from better implementing actions to deal with the effects of climate change on your site?	"No," "Knowledge on site vulnerability," "Knowledge on conservation actions useful to implement the RAD framework," "Capacity building," "Funding," "Time," "Consensus with stakeholders," "Other"

3 | Results

We obtained 382 answers from 25 different countries (see Zavattoni et al. 2025 for survey details).

3.1 | Vulnerability to Climate Change

Perceived vulnerability to climate change was reported in 59.7% of the responses (228/382), primarily due to precipitation changes and warming (Figure 1; Appendix S3).

Among responses reporting perceived vulnerability, only 7.0% (16/228) came from N2K sites whose SDFs also mentioned climate change as a threat. In contrast, 4.5% (7/154) of responses that did not report it as a threat came from sites whose SDFs included climate change as a threat.

Overall perceived vulnerability to climate change was not significantly different across biogeographical regions (Figure 2b; Appendix S4). Respondents from the Mediterranean region perceived higher vulnerability to warming ($p = 0.02$; Figure 2b; Appendix S5) and to precipitation changes ($p = 0.03$; Figure 2b; Appendix S6) than respondents from the Boreal region. Both Boreal and Continental regions were perceived as less vulnerable to extreme events than the Mediterranean ($p < 0.01$ and $p = 0.03$, respectively; Figure 2b; Appendix S7).

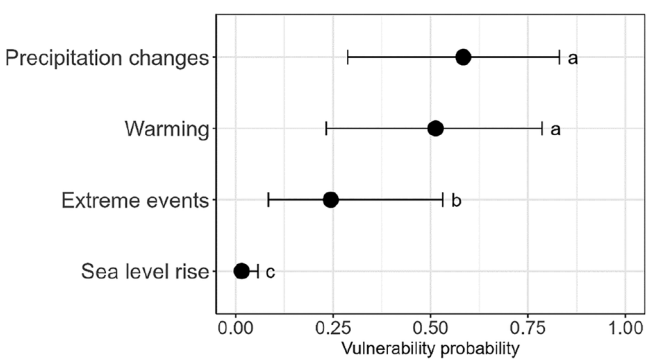

FIGURE 1 | Predicted probabilities (± 95% CI) that a manager reported perceived vulnerability to different aspects of climate change. Vulnerability categories whose probabilities are statistically different from each other at $p < 0.05$ are marked with different letters; that is, shared letters indicate no difference.

3.2 | Climate Change Management

Climate change was considered in management by 58.4% (223/382) of the respondents. Managers that perceived their site as vulnerable were two times more likely to have implemented climate adaptation strategies ($\beta = 1.85 \pm 0.47$, $p < 0.001$; Figure 3). However, 29.8% (68/228) of the managers in vulnerable sites reported no adaptation strategies, or were unsure about their

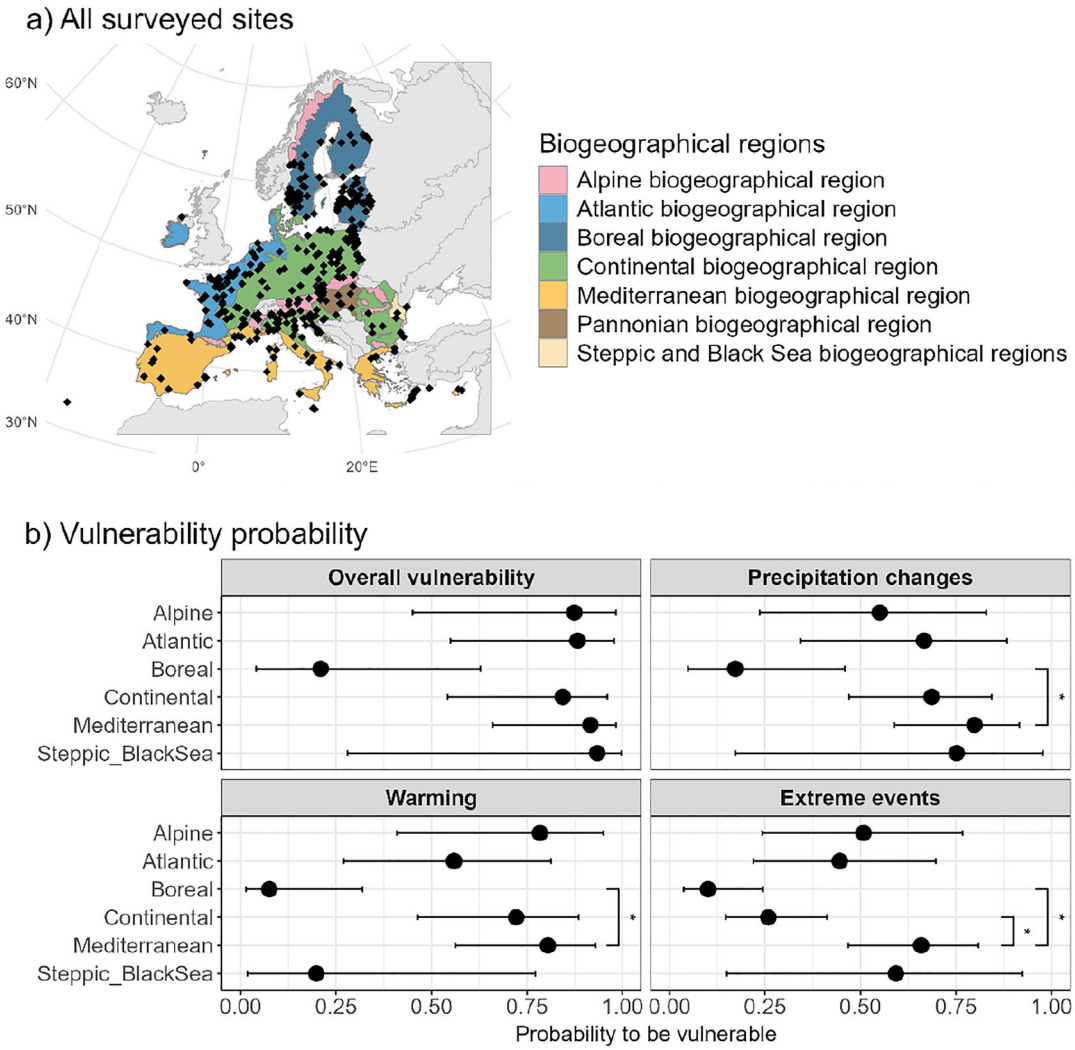

FIGURE 2 | (a) Surveyed Natura 2000 sites across European biogeographical regions. One location is shown for multiple overlapping sites. (b) Predicted probability (± 95% CI) of reporting vulnerability to different climate-change-related threats across biogeographical regions. Significantly different comparisons at $p < 0.05$ are marked with *.

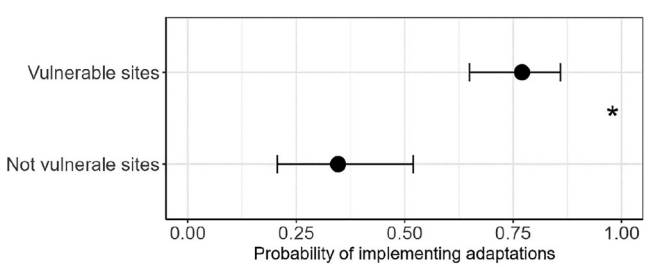

FIGURE 3 | Predicted probabilities (± 95% CI) of reporting the implementation of climate change adaptation strategies, based on whether the surveyed Natura 2000 site was reported in the previous questions as vulnerable to climate change or not. Significant difference is marked with * (p-value < 0.05).

presence. Managers that did not implement any climate change-adaptations were more likely to perceive their site as less vulnerable to it ($\beta = -1.16 \pm 0.47$, $p = 0.01$; Appendix S8a), whereas no clear distinction was found with managers that were unsure if they had implemented adaptation strategies ($\beta = -0.75 \pm 0.41$, $p = 0.07$; Appendix S8b).

Contrary to our hypothesis, managers' reported categorization of implemented climate change adaptation strategies (from 223 site) was relatively well balanced between resist, accept, and direct approaches (Figure 4). Resisting the effects of climate change (probability = 0.84 ± 0.07) was more frequent than accepting (probability = 0.61±0.11; $\beta = 1.21 \pm 0.27$, $p < 0.01$), but not more than directing (probability = 0.74±0.1; $\beta = 0.63 \pm 0.27$, $p = 0.05$). Directing and accepting actions were not statistically different ($\beta = 0.59 \pm 0.26$, $p = 0.06$).

The most likely reported implementation barrier to climate change adaptation strategies was lack of funding. Lack of knowledge on site vulnerability was more likely to be reported as a barrier than lack of knowledge on RAD actions. The probability of having no issues (i.e., challenges) in implementing adaptation strategies was scarce, that is, 0.08 ± 0.02 (Figure 5; Appendix S9).

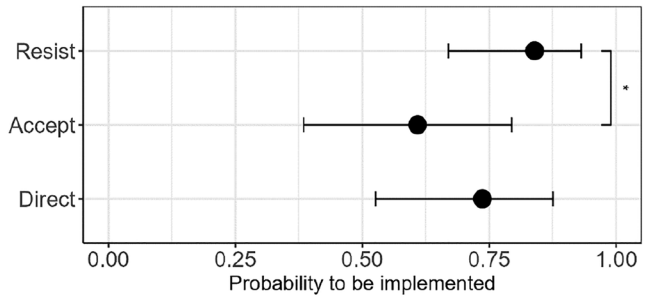

FIGURE 4 | Predicted probabilities (± 95% CI) of the implementation of different RAD approaches (Resist, Accept, Direct) in Natura 2000 sites reporting the implementation of climate change adaptation strategies ($n = 223$). Significant differences are marked with * (p-value < 0.05).

4 | Discussion

We found climate change to be perceived as a frequent threat by N2K site managers in the EU, 10 times more than reported in the most recent N2K official information for the surveyed sites. Furthermore, perception of vulnerability varies across biogeographical regions and depends on climate change aspects. Encouragingly, the implementation of climate change adaptations is reported by 58% of the surveyed managers, which is markedly more than what has been found in national studies (Sousa-Silva et al. 2016, EC 2025). Despite reporting funding and knowledge limitations to implement adaptation strategies, we find, contrary to our expectation, that managers report using a variety of strategies that not only resist the effects of climate change. However, categorizing management strategies into a RAD framework may have been new to many managers and thus, despite the explanation provided, some subjectivity may persist, as we did not assess how the categorization was made.

Climate change is a multidimensional phenomenon, so understanding how its various aspects threaten biodiversity on a local scale is essential for effective management (Pearce-Higgins et al. 2019). We found that N2K managers were more concerned about long-term changes in temperature and precipitation than extreme climatic events. This is surprising, as both long-term trends and extreme events are known to synergistically impact biodiversity (Harris et al. 2018; Ly and Diffenbaugh 2025). While sea level rise was rarely reported as a threat due to its association only with coastal areas, it can nonetheless have major impacts on N2K sites (van de Wal et al. 2024; Verniest et al. 2024).

In most surveyed N2K sites, managers' vulnerability assessment did not correspond to what was reported in the SDFs, highlighting an important mismatch between perceived vulnerability and information reported officially to the EU Commission (Zavattoni et al. 2025). Although SDFs are intended to be updated regularly by legal authorities, including managers, the update frequency is likely low and heterogeneous. With only 7% consistency between our survey (years 2023–2024) and the latest SDFs update (2021), our results suggest that threat assessments based on the official N2K data could strongly underestimate climate change vulnerability. While it was encouraging to observe that managers act on their perception of vulnerability rather than on SDFs information, the lack of updates is still concerning, given that SDFs are used by the EU Commission for several purposes, such as funding allocations and assessing possible violations of environmental law (EC 2011). Similarly, while we expected adaptation strategies to be implemented by a few managers only, 58% of them already done so, although a gap persisted since around one third of the vulnerable sites did not implement adaptations.

Our survey's explicit focus on climate change may have biased participation toward managers already engaged with it and the Natur'Adapt LIFE+ campaign promoted the importance of climate adaptations just before our study. While these factors can partly explain the high rates of perceived vulnerability and adaptation strategies, they are unlikely to explain the marked gap between threats reported in our survey and in the SDFs.

4.1 | Biogeographical Regional Contrasts

Managers in the Boreal region were the least worried about each aspect of climate change, while managers in the Mediterranean expressed the most concern. The Mediterranean is a known hotspot of climate change (Tuel and Eltahir 2020), especially due to an increase in extreme events (Giorgi and Lionello 2008; Hoerling et al. 2012), and its biodiversity is particularly sensitive to it (Newbold et al. 2020). Finding that managers perceived lower vulnerability in the Boreal region was surprising, as this has been warming faster than the rest of Europe (EEA 2009). One possible explanation is that species richness in Northern Europe has increased as a consequence of climate change (Thuiller et al. 2011). However, the lack of perceived vulnerability remains concerning as cold-adapted species are negatively affected (Mäkinen et al. 2025; Stubbs et al. 2018). Management in Northern countries have the increasingly important role of both accommodating the growing number of warm-dwelling species shifting northward, while still trying to prevent the loss of native cold-dwelling ones.

Although survey answers were well spread across European biogeographical regions (Zavattoni et al. 2025), some spatial clustering may exist, as the same manager may have filled the questionnaire for multiple sites and managers working nearby may share similar views. We corrected the residual spatial autocorrelation in the models, though we cannot account for individual perception as we did not collect respondent information. Additionally, our results provide an overview of managers' perceptions but they cannot be directly compared with actual vulnerability without more details on perceived and actual N2K site conditions.

4.2 | RAD Application

Contrary to our hypothesis, managers' characterizations of their implemented adaptation strategies were relatively well balanced across the categories of resist, accept, and direct. While strategies based on resisting climate change were as likely as directing, they were more likely than accepting. Resisting has been the traditional, often implicit, approach to conservation, which historically viewed ecosystems as stationary entities (Milly et al. 2008; Schuurman et al. 2020). Furthermore, the design of the N2K network possibly favors a resisting approach, since each site is

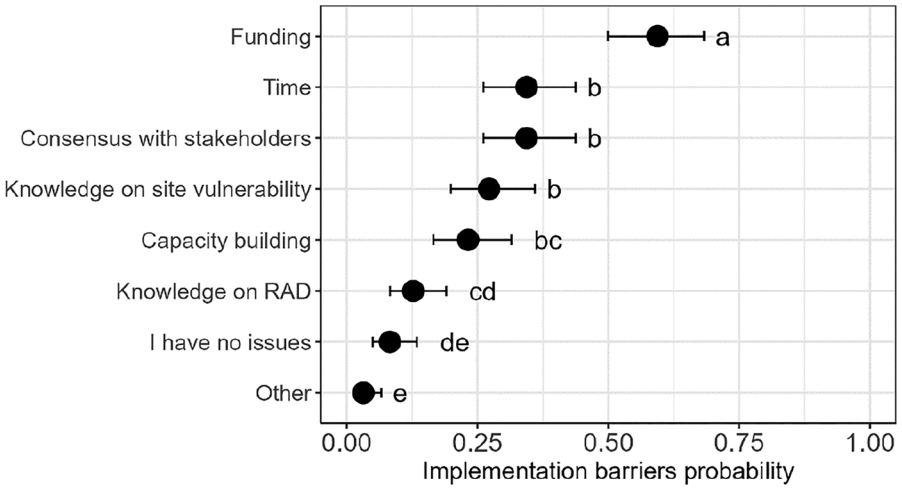

FIGURE 5 | Predicted probabilities (± 95% CI) of reporting different barriers to the implementation of climate change adaptation strategies, considered only for sites that reported implementing adaptation strategies ($n = 223$). Vulnerability categories whose probabilities are statistically different from each other at $p < 0.05$ are marked with different letters; that is, shared letters indicate no difference.

designated with specific species and/or habitat targets, creating a legal obligation for managers to protect these. Directing and accepting approaches are, however, used in over half of the sites addressing climate change, highlighting that N2K managers are open to dynamic management. Resisting is a crucial strategy, especially for conserving species with limited ranges and reduced possibility to shift. However, directing and accepting are needed to more broadly facilitate species responses to climate change, in particular where long term resistance may be costly and unfeasible (Lynch et al. 2021; Schuurman et al. 2020). Ideally, management decisions should be made case-by-case through network-level cooperation and trade-offs between different protected areas. If a site accepts the loss of a species due to the changing climate, it is crucial to ensure that the same species still receives enough protection elsewhere.

4.3 | Removing Barriers Through Funding and Scientific Knowledge

Our results indicate that many barriers prevent N2K managers from better implementing climate change adaptation strategies. The most widespread barriers are generic management challenges, not necessarily linked to climate change only, such as lack of funding and time, and difficulties in getting consensus with stakeholders (Geitzenauer et al. 2017; Kati et al. 2015). However, around one-third of the managers also highlighted as a barrier the lack of knowledge regarding the site's vulnerability to climate change. While the scientific literature on climate change vulnerability has been increasing in recent years, this may not be easily accessible by managers. Earlier research into the perceptions of N2K forest managers revealed that they found climate change predictions too vague to be useful at a local level and they struggled due to the absence of knowledge on actionable measures (de Koning et al. 2014). These now decade-old findings are echoed in ours and highlight the need to make scientific outcomes more accessible to better support managers' decision-making processes (EC 2026).

5 | Conclusions

While reducing greenhouse gas emissions must be a priority, current trends suggest that carbon neutrality will not be achieved soon, making it essential to manage climate change impacts on biodiversity locally. Among the surveyed N2K managers, climate change is already perceived as a widespread threat, which is being managed not only by resisting its impacts, but also by accepting and directing them. However, we identified several knowledge and resource-based barriers in implementing adaptation strategies that must be addressed. Science needs to take an increasingly important role in aiding managers by producing actionable knowledge, while funding and capacity building support are needed to improve research-management synergies and the implementation of adaptation strategies.

Acknowledgments

We thank the translators, Eurosite, and the managers. Funding was provided by Kone Foundation (Application 202103360) and Biodiversa+ (2021–2022 BiodivProtect program), with: Ympäristöministeriö (VN/7162/2023), Vetenskapsrådet (Swedish University of Agricultural Science: 2022-01752), Research Council of Norway (Norwegian Institute for Nature Research: 342927), Innovation Fund Denmark (Aarhus University: 1159-00033B), Swiss National Science Foundation (Swiss Ornithological Institute: 20BD21_209665), and Ministerio de Ciencia e Innovación; Agencia Estatal de Investigación (CREAF: PCI2022-135056-2).

Open access publishing facilitated by Turun yliopisto, as part of the Wiley – FinELib agreement.

Funding

The research was funded by the Kone Foundation (Application 202103360) and Biodiversa+ (2021–2022 BiodivProtect program), with the following organizations: Ympäristöministeriö (VN/7162/2023), Vetenskapsrådet (Swedish University of Agricultural Science: 2022-01752), Research Council of Norway (Norwegian Institute for Nature Research: 342927), Innovation Fund Denmark (Aarhus University: 1159-00033B), Swiss National Science Foundation (Swiss Ornithological Institute:

20BD21_209665), and Ministerio de Ciencia e Innovación; Agencia Estatal de Investigación (CREAF: PCI2022-135056-2).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data and the code are available in Zenodo (DOI: https://doi.org/10.5281/zenodo.19232597).

References

Anderson, S. C., E. J. Ward, P. A. English, et al. 2024. "sdmTMB: An R Package for Fast, Flexible, and User-Friendly Generalized Linear Mixed Effects Models With Spatial and Spatiotemporal Random Fields." *bioRxiv*. https://doi.org/10.1101/2022.03.24.485545.

Araújo, M. B., D. Alagador, M. Cabeza, et al. 2011. "Climate Change Threatens European Conservation Areas." *Ecology Letters* 14, no. 5: 484–492. https://doi.org/10.1111/j.1461-0248.2011.01610.x.

Bowgen, K. M., E. F. Kettel, S. H. M. Butchart, et al. 2022. "Conservation Interventions Can Benefit Species Impacted by Climate Change." *Biological Conservation* 269: 109524. https://doi.org/10.1016/j.biocon.2022.109524.

de Koning, J., E. Turnhout, G. Winkel, et al. 2014. "Managing Climate Change in Conservation Practice: An Exploration of the Science–Management Interface in Beech Forest Management." *Biodiversity and Conservation* 23, no. 14: 3657–3671. https://doi.org/10.1007/s10531-014-0781-8.

European Commission (EC). 2011. "Commission Implementing Decision of 11 July 2011 Concerning a Site Information Format for Natura 2000 Sites (2011/484/EU)." https://faolex.fao.org/docs/pdf/eur104745.pdf.

European Commission (EC). 2025. "Adapting Nature Protection to the Challenges of Climate Change in Europe—Basis of Dynamic Collective Learning (LIFE17 CCA/FR/000089)." LIFE Public Website. https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE17-CCA-FR-000089/adapting-nature-protection-to-the-challenges-of-climate-change-in-europe-basis-of-dynamic-collective-learning (accessed on 24.06.2025).

European Commission (EC). 2026. "Guidance on Adapting Natura 2000 Sites to Climate Change." (accessed on 26.03.2026) https://environment.ec.europa.eu/publications/guidance-adapting-natura-2000-sites-climate-change_en.

European Environment Agency (EEA). 2009. "Observed Temperature Change Over Europe 1976–2006." https://www.eea.europa.eu/en/analysis/maps-and-charts/observed-temperature-change-over-europe-1976-2006 (accessed on 02.10.2025).

European Environment Agency (EEA). 2021. "Natura 2000—Comma Separated Values Files [Data set]." (accessed on 24.06.2025) https://www.eea.europa.eu/data-and-maps/data/natura-14/natura-2000-tabular-data-12-tables/natura-2000-comma-separated-values-files.

European Environment Agency (EEA). 2025. "Biogeographical Regions [Data set]." (accessed on 24.06.2025) https://www.eea.europa.eu/en/datahub/datahubitem-view/11db8d14-f167-4cd5-9205-95638dfd9618.

Gaget, E., D. Pavón-Jordán, A. Johnston, et al. 2021. "Benefits of Protected Areas for Nonbreeding Waterbirds Adjusting Their Distributions Under Climate Warming." *Conservation Biology* 35, no. 3: 834–845. https://doi.org/10.1111/cobi.13648.

Geitzenauer, M., M. Blondet, J. De Koning, et al. 2017. "The Challenge of Financing the Implementation of Natura 2000—Empirical Evidence From Six European Union Member States." *Forest Policy and Economics* 82: 3–13. https://doi.org/10.1016/j.forpol.2017.03.008.

Giorgi, F., and P. Lionello. 2008. "Climate Change Projections for the Mediterranean Region." *Global and Planetary Change* 63, no. 2: 90–104. https://doi.org/10.1016/j.gloplacha.2007.09.005.

Greenwood, O., H. L. Mossman, A. J. Suggitt, R. J. Curtis, and I. M. D. Maclean . 2016. "Using in Situ Management to Conserve Biodiversity Under Climate Change." *Journal of Applied Ecology* 53, no. 3: 885–894. https://doi.org/10.1111/1365-2664.12602.

Harris, R. M., L. J. Beaumont, T. R. Vance, et al. 2018. "Biological Responses to the Press and Pulse of Climate Trends and Extremeevents." *Nature climate change* 8, no. 7: 579–587.

Hartig, F. 2022. "_DHARMa: Residual Diagnostics for Hierarchical (Multi-Level /Mixed) Regression Models_." R package version 0.4.6, https://CRAN.R-project.org/package=DHARMa.

Hoerling, M., J. Eischeid, J. Perlwitz, X. Quan, T. Zhang, and P. Pegion. 2012. "On the Increased Frequency of Mediterranean Drought." *Journal of Climate* 25, no. 6: 2146–2161.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. 2019. "Global Assessment Report on Biodiversity and Ecosystem Services." IPBES.

Kati, V., T. Hovardas, M. Dieterich, P. L. Ibisch, B. Mihok, and N. Selva. 2015. "The Challenge of Implementing the European Network of Protected Areas Natura 2000." *Conservation Biology* 29, no. 1: 260–270. https://doi.org/10.1111/cobi.12366.

Lenth, R. 2023. "_emmeans: Estimated Marginal Means, aka Least-Squares Means_." R package version 1.8.8, https://CRAN.R-project.org/package=emmeans.

Ly, A., and N. S. Diffenbaugh. 2025. "Integrating Climate Extremes With Key Biodiversity Areas for Improved Biodiversity Risk Analysis and Protected Area Planning." *Conservation Science and Practice* 7, no. 12: e70190.

Lynch, A. J., L. M. Thompson, E. A. Beever, et al. 2021. "Managing for RADical Ecosystem Change: Applying the Resist-Accept-Direct (RAD) Framework." *Frontiers in Ecology and the Environment* 19, no. 8: 461–469. https://doi.org/10.1002/fee.2377.

Magness, D. R., L. Hoang, R. T. Belote, et al. 2022. "Management Foundations for Navigating Ecological Transformation by Resisting, Accepting, or Directing Social–Ecological Change." *Bioscience* 72, no. 1: 30–44.

Mäkinen, J., E. E. Ellis, L. H. Antão, et al. 2025. "Thermal Homogenization of Boreal Communities in Response to Climate Warming." *Proceedings of the National Academy of Sciences* 122, no. 17: e2415260122.

Milly, P. C. D., J. Betancourt, M. Falkenmark, et al. 2008. "Stationarity Is Dead: Whither Water Management?." *Science* 319, no. 5863: 573–574.

Newbold, T., P. Oppenheimer, A. Etard, and J. J. Williams. 2020. "Tropical and Mediterranean Biodiversity Is Disproportionately Sensitive to Land-Use and Climate Change." *Nature Ecology & Evolution* 4, no. 12: 1630–1638. https://doi.org/10.1038/s41559-020-01303-0.

Nila, M. U. S., C. Beierkuhnlein, A. Jaeschke, S. Hoffmann, and M. L. Hossain. 2019. "Predicting the Effectiveness of Protected Areas of Natura 2000 Under Climate Change." *Ecological Processes* 8, no. 1: 13. https://doi.org/10.1186/s13717-019-0168-6.

Pearce-Higgins, J. W., P. J. Lindley, I. G. Johnstone, R. I. Thorpe, D. J. T. Douglas, and M. C. Grant . 2019. "Site-Based Adaptation Reduces the Negative Effects of Weather Upon a Southern Range Margin Welsh Black Grouse Tetrao Tetrix Population That Is Vulnerable to Climate Change." *Climatic Change* 153, no. 1: 253–265. https://doi.org/10.1007/s10584-019-02372-2.

R Core Team. 2022. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Schuurman, G., H.-H. Cat, D. Cole, et al. 2020. "Resist-Accept-Direct (RAD)—A Framework for the 21st-Century Natural Resource Manager." National Park Service. https://doi.org/10.36967/nrr-2283597.

Schuurman, G. W., D. N. Cole, A. E. Cravens, et al. 2022. "Navigating Ecological Transformation: Resist–Accept–Direct as a Path to a New Resource Management Paradigm." *Bioscience* 72, no. 1: 16–29. https://doi.org/10.1093/biosci/biab067.

Sousa-Silva, R., Q. Ponette, K. Verheyen, A. Van Herzele, and B. Muys. 2016. "Adaptation of Forest Management to Climate Change as Perceived by Forest Owners and Managers in Belgium." *Forest Ecosystems* 3, no. 1: 22. https://doi.org/10.1186/s40663-016-0082-7.

Stubbs, R. L., D. E. Soltis, and N. Cellinese. 2018. "The Future of Cold-Adapted Plants in Changing Climates: Micranthes (Saxifragaceae) as a Case Study." *Ecology and evolution* 8, no. 14: 7164–7177.

Thuiller, W., S. Lavergne, C. Roquet, I. Boulangeat, B. Lafourcade, and M. B. Araujo . 2011. "Consequences of Climate Change on the Tree of Life in Europe." *Nature* 470, no. 7335: 531–534. https://doi.org/10.1038/nature09705.

Tuel, A., and E. a. B. Eltahir. 2020. "Why Is the Mediterranean a Climate Change Hot Spot?" *Journal of Climate* 33, no. 14: 5829–5843. https://doi.org/10.1175/JCLI-D-19-0910.1.

van de Wal, R., A. Melet, D. Bellafiore, et al. 2024. "Sea Level Rise in Europe: Impacts and Consequences." *State of the Planet Discussions* 3-slre1: 5. https://doi.org/10.5194/sp-3-slre1-5-2024.

Verniest, F., T. Galewski, O. Boutron, et al. 2024. "Exposure of Wetlands Important for Nonbreeding Waterbirds to Sea-Level Rise in the Mediterranean." *Conservation Biology* 38, no. 6: e14288.

Zavattoni, G., E. Gaget, T. Hallman, et al. 2025. "Threats to and Management of Natura 2000 Protected Areas Relative to Agricultural Practices." *Conservation Biology* 40, no. 2: e70172. https://dx.doi.org/10.1111/cobi.70172.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supplementary Appendix: conl70047-sup-0001-Appendix.docx