Biological Conservation 303 (2025) 111026

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

EU nature restoration law fails to recognize missing large herbivore functions

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The newly passed European Nature Restoration Law (NRL; Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869), urge EU member states to restore at least 20 % of degraded natural areas by 2030, and ultimately all ecosystems in need of restoration by 2050. The European NRL fails however, in recognizing the defaunated nature of European ecosystems; probably due to environmental generational amnesia as the experiential baseline has shifted (Hartig and Kahn, 2016). In the articulation of the law, article 3 defines ecosystem as “a dynamic complex of plant, animal, fungi and microorganism communities and their non-living environment, interacting as a functional unit, and includes habitat types, habitats of species and species populations”, in which trophic rewilding (sensu Svenning et al., 2016) interventions could be applied to (self-) restore ecosystem processes and functions, and therefore boost biodiversity, ecosystem complexity and resilience. One of the issues in implementing a restoration strategy that is dynamic in nature, is the fact that is not fixed to specific restoration benchmarks as it has been traditionally applied restoration and nature conservation under the Habitats Directive (Directive 92/43/EEC of 21 June on the conservation of natural habitats and of wild fauna and flora), from which the new NRL stems. Therefore, despite good intentions and a comprehensive and elaborated articulation of the law, it fails to recognize the paramount importance of missing large herbivore grazers in today’s European ecosystems. Indeed, the ongoing worldwide collapse of large mammals, including both carnivores and herbivores, is noted as a major driver of global change (see, Dirzo et al., 2014; Malhi et al., 2016; Ripple et al., 2015).

In contrast with the currently simplified herbivore communities and downgraded ecosystems of EU, recent research has shown that large and megaherbivores (> 45 kg body mass) were fundamental components of former European landscapes, playing key roles in ecosystem functioning and maintaining open landscape structures (Pearce et al., 2023). Such open landscape structures were engineered by highly functionally diverse herbivore communities, with a mean loss in species richness from the Last Interglacial period (a period suggested as the closest analogue to present day climate but without human influence) to the present estimated at 70.8 % (Davoli et al., 2024). That significant herbivore diversity demise hinders the ability of megaherbivore faunas to exert their ecological functions and provide natural climate solutions (Fricke et al., 2022; Schmitz et al., 2023). Hence restoring the diversity of large herbivore communities is fundamental for future ecosystem restoration efforts, provided that a reference natural baseline for large-herbivore biomass in ecological restoration is agreed (see, Fløjgaard et al., 2022), to fulfill their functional roles across landscapes; a key question in trophic rewilding. Yet, classic conservation and restoration has traditionally focused on a baseline set after 1500 CE, a time when ecosystems were already highly depleted (Donlan et al., 2006; Monsarrat and Svenning, 2022).

Groundbreaking research 20 years back demonstrated that climate alone did not determine the global distribution of different habitats and biomes (Bond, 2005). For a given set of climatic conditions, a range of landscapes from pure grasslands to thick forest ecosystems could be developed based on two influential consumers at play, namely large mammalian herbivores and fire. Therefore, large parts of the planet ecosystems do not seem to be at equilibrium with climate but rather consumer-controlled (Bond, 2005), including European ecosystems. This has paramount consequences for nature restoration as highlights the dynamic nature of ecosystems and provide the main tools for achieving different restoration outcomes.

In order to implement trophic rewilding principles in the new NRL, two aspects need to be amended: 1. To incorporate the definition of taxon, and to include extinct species or extant functional proxies for restoration purposes rather than focusing solely on typical species for a certain habitat type. Hence, in the definition of “favorable conservation status for a habitat or species” the possibility to implement functional process-oriented approaches to enhance the quantity and quality of

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https://doi.org/10.1016/j.biocon.2025.111026
Received 28 October 2024; Received in revised form 28 January 2025; Accepted 9 February 2025
Available online 12 February 2025

certain habitat or species population could be envisioned via trophic rewilding, and 2. To open the possibility for creating different benchmarks and indicators based on boosting biodiversity and ecosystem complexity, while tracking changes in ecosystem processes and functions via functional trait ecology approaches (see, Atkinson et al., 2024; Garrido et al., 2019).

There is increasing evidence of the important role that large animals play for biodiversity and ecosystem functioning (e.g., Enquist et al., 2020; Estes et al., 2011; Galetti et al., 2018; Malhi et al., 2016) which has triggered strong scientific interest on large and megaherbivore fauna in conservation, restoration and climate change mitigation (Cromsigt et al., 2018; Malhi et al., 2022; Svenning et al., 2024a). Moreover, in current European ecosystems, large herbivores could function as megaherbivores based on 1. Adult body mass makes them immune to natural predation control and therefore "landscape of fear" effects (Laundré et al., 2001) and 2. Their greater nutritional requirements, including low quality resources, leads to strong impacts on lower trophic levels (Owen-Smith, 1987; Svenning et al., 2024b). Thus, re-introducing some of the recently extinct large and megaherbivores would significantly boost biodiversity, ecosystem complexity and resilience while providing natural climate solutions. As such, European bison (*Bison bonasus*), European wild ass (*Equus hydruntinus*), aurochs (*Bos taurus*) and tarpans (*Equus ferus*) were an integral component of primeval European ecosystems that were later extinct or replaced by their domestic forms. Today there are no ecologically functional wild or free ranging (feral) large herbivore grazers in Europe, except for a few local cases in natural reserves (e.g., Rodríguez-Rodríguez et al., 2022) and therefore, without recognizing that missing large herbivores or ecological replacement taxons are essential components of the ecosystems envisioned to restore, future restoration programs and natural climate solutions may render futile. Furthermore, most large herbivore grazers are still considered livestock, i.e., commodities for human consumption, thus failing in the recognition of their ecological functions. Lundgren et al. (2024) demonstrated that herbivore communities dominated by nonselective bulk feeders (true grazers) contribute the most to plant diversity globally irrespective of normative values associated to them such as "native", "introduced", "invasive" or "feral". For instance, equids exert ecosystem engineering functions that include changes in the functional composition of grasslands (Garrido et al., 2019), forest structural and compositional changes (Garrido et al., 2021), enhance water availability (Lundgren et al., 2021) as well as create different microhabitats such as defecation concentration (latrines) (Garrido et al., 2022) and wallowing areas that support a higher arthropod diversity (van Klink et al., 2015). Thus large herbivores create environmental heterogeneity, supply nutrients, reduce wildfire risks, stabilize soils and enhance plant dispersal and germination services (Schmitz et al., 2023, and references therein).

In conclusion, neglecting the inclusion of European bison and missing equids and bovids, as proxies of wild herbivore grazers, as fundamental components for future restoration efforts via trophic rewilding, may jeopardize the much needed restoration of European ecosystems. This aligns with EU and international commitments such as the Paris Climate Agreement to foster natural climate solutions to tackle the ongoing biodiversity and climate crises. It would further facilitate a sustainable future for humans in a resilient Europe in line with the foundational principles of the new European NRL. Yet, this may not materialize without a necessary paradigm and political change. It is therefore crucial to ignite discussions with policy makers and practitioners to implement the necessary changes and to make this very important law fully functional for nature restoration to urgently reverse the current situation of European ecosystems from which our own survival as species depends upon.

CRediT authorship contribution statement

Pablo Garrido: Writing – review & editing, Writing – original draft, Conceptualization. **Carl-Gustaf Thulin:** Writing – review & editing. **Juan José Negro:** Writing – review & editing.

Declaration of Generative AI and AI-assisted technologies in the writing process

The corresponding author confirms on behalf of all authors that during the preparation of this work the authors did not use any AI tool.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The corresponding author confirms on behalf of all authors that there have been no involvements that might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated.

Acknowledgements

We would like to thank two anonymous reviewers for their suggestions to improve earlier drafts of the manuscript.

Data availability

No data was used for the research described in the article.

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