Identification of areas of very high biodiversity value to achieve the EU Biodiversity Strategy for 2030 key commitments
Iulia V Miu
Laurentiu Rozylowicz
Viorel D Popescu
Paulina Anastasiu
journal article
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Identification of areas of very high biodiversity value to achieve the EU Biodiversity Strategy for 2030 key commitments

Iulia V Miu [1], **Laurentiu Rozylowicz** [Corresp., 1, 2], **Viorel D Popescu** [1, 3], **Paulina Anastasiu** [4]

[1] Center for Environmental Research, University of Bucharest, Bucharest, Romania

[2] Chelonia Romania, Bucharest, Romania

[3] Department of Biological Sciences, Ohio University, Athens, Ohio, United States

[4] Dimitrie Brândză Botanical Garden, University of Bucharest, Bucharest, Romania

Corresponding Author: Laurentiu Rozylowicz
Email address: laurentiu.rozylowicz@g.unibuc.ro

Background

The European Union strives to increase protected areas of the EU terrestrial surface to 30% by year 2030, of which one third should be strictly protected. Designation of the Natura 2000 network, the backbone of nature protection in the EU, was mostly an expert-opinion process with little systematic conservation planning. The designation of the Natura 2000 network in Romania followed the same non-systematic approach, resulting in a suboptimal representation of invertebrates and plants. To help identify areas with very high biodiversity without repeating past planning missteps, we present a reproducible example of spatial prioritization using Romania's current terrestrial Natura 2000 network and coarse-scale terrestrial species occurrence.

Methods

We used 371 terrestrial Natura 2000 Sites of Community Importance (Natura 2000 SCI), designated to protect 164 terrestrial species listed under Annex II of Habitats Directive in Romania in our spatial prioritization analyses (marine Natura 2000 sites and species were excluded). Species occurrences in terrestrial Natura 2000 sites were aggregated at a Universal Traverse Mercator spatial resolution of 1 km^2. To identify priority terrestrial Natura 2000 sites for species conservation, and to explore if the Romanian Natura 2000 network sufficiently represents species included in Annex II of Habitats Directive, we used Zonation v4, a decision support software tool for spatial conservation planning. We carried out the analyses nationwide (all Natura 2000 sites) as well as separately for each biogeographic region (i.e., Alpine, Continental, Pannonian, Steppic and Black Sea).

Results

The results of spatial prioritization of terrestrial Natura 2000 vary greatly by planning scenario. The performance of national-level planning of top priorities is minimal. On average, when 33% of the landscape of Natura 2000 sites is protected, only 20% of the distribution of species listed in Annex II of Habitats Directive are protected. As a consequence, the representation of species by priority terrestrial Natura 2000 sites is lessened when compared to the initial set of species. When planning by taxonomic group, the top-priority areas include only 10% of invertebrate distribution in Natura 2000. When selecting top-priority areas by biogeographical region, there are significantly fewer gap species than in the national

level and by taxa scenarios; thusly, the scenario outperforms the national-level prioritization. The designation of strictly protected areas as required by the EU Biodiversity Strategy for 2030 should be followed by setting clear objectives, including a good representation of species and habitats at the biogeographical region level.

1 **Identification of areas of very high biodiversity value**
2 **to achieve the EU Biodiversity Strategy for 2030 key**
3 **commitments**

5 Iulia V. Miu[1], Laurentiu Rozylowicz[1,2], Viorel D. Popescu[1,3], Paulina Anastasiu[4]

7 [1] Center for Environmental Research, University of Bucharest, Bucharest, Romania
8 [2] Chelonia Romania, Bucharest, Romania
9 [3] Department of Biological Sciences, Ohio University, Athens, Ohio, United States of America
10 [4] Dimitrie Brândză Botanical Garden, University of Bucharest, Bucharest, Romania

12 Corresponding Author:
13 Laurentiu Rozylowicz[1]
14 1 N. Balcescu, Bucharest, 010041, Romania
15 Email address: laurentiu.rozylowicz@g.unibuc.ro

Abstract

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The results of spatial prioritization of terrestrial Natura 2000 vary greatly by planning scenario. The performance of national-level planning of top priorities is minimal. On average, when 33% of the landscape of Natura 2000 sites is protected, only 20% of the distribution of species listed in Annex II of Habitats Directive are protected. As a consequence, the representation of species by priority terrestrial Natura 2000 sites is lessened when compared to the initial set of species. When planning by taxonomic group, the top-priority areas include only 10% of invertebrate distribution in Natura 2000. When selecting top-priority areas by biogeographical region, there are significantly fewer gap species than in the national level and by taxa scenarios; thusly, the scenario outperforms the national-level prioritization. The designation of strictly protected areas

49 as required by the EU Biodiversity Strategy for 2030 should be followed by setting clear

50 objectives, including a good representation of species and habitats at the biogeographical region

51 level.

52

Introduction

54 Protected areas, a critical tool for nature conservation strategies, are intended to ensure the long-

55 term persistence and viability of biodiversity. These areas should support many rare, threatened,

56 or endemic taxa, particularly those with low mobility and high sensitivity to environmental

57 alterations as possible (Geldmann et al. 2013; Gray et al. 2016; Possingham et al. 2006;

58 Rodrigues et al. 2004). When planning protected areas, states around the world are guided by

59 supranational policies such as Convention on Biological Diversity and EU Biodiversity Strategy

60 for 2030, which issue ambitious objectives to increase the extent of protected areas. For example,

61 Convention on Biological Diversity (CDB) Aichi Target on Protected Areas calls for the

62 protection of 17% of the world's terrestrial and inland water areas in key regions for biodiversity

63 and ecosystem services (UNEP 2011), while the EU Member States seek to increase by 2030 the

64 Natura 2000 network to 30% of which one third should be under strict protection as areas of very

65 high biodiversity and climate value (European Commission 2020).

66 A promising tool to help build an ecologically-sound network of protected areas meeting the

67 CDB or EU targets is systematic conservation planning (Margules & Pressey 2000). Systematic

68 conservation planning maximizes conservation benefits while minimizing impacts on other

69 resources, such as the availability of productive land. Spatial conservation prioritization, as a part

70 of systematic conservation planning, customarily relies on the complementarity concept (i.e.,

71 selection of complementary areas to avoid duplication of conservation effort) and is considered

72 an efficient instrument for identifying spatial priorities and achieving conservation goals

73 (Margules & Pressey 2000; Pressey et al. 2007).

74 One of the most extensive networks of conservation areas in the world is the Natura 2000

75 network, which has been created to operationalize EU Birds (Directive 2009/147/EC) and

76 Habitats Directives (Council Directive 92/43/EEC). To date, Natura 2000 encompasses 18% of

77 EU terrestrial area, thus meeting the CDB Aichi Target on Protected Areas (UNEP 2011). The

78 effectiveness and representativity of Natura 2000 were evaluated for different taxonomic groups

79 and geographic areas, and the conclusions tended to highlight suboptimal planning (D'Amen et

80 al. 2013; Dimitrakopoulos et al. 2004; Kukkala et al. 2016; Lisón et al. 2013; Müller et al. 2018;

81 Müller et al. 2020; Votsi et al. 2016). The suboptimal planning of Natura 2000 at the EU and at

82 Member States levels originates from an uncoordinated process (Apostolopoulou & Pantis 2009;

83 Iojă et al. 2010; Lisón et al. 2017; Orlikowska et al. 2016), which was partially resolved by

84 selecting new sites after expert-opinion evaluations during the Natura 2000 biogeographical

85 seminars (Kenig-Witkowska 2017; Manolache et al. 2017). Furthermore, the efficacy of the

86 Natura 2000 network was extensively re-evaluated from other perspectives, for example, for

87 understanding the effect of climate change on representativity (Araújo et al. 2011; Popescu et al.

88 2013) and for coordinating conservation investments (Hermoso et al. 2017; Nita et al. 2016).

89 The designation of the Natura 2000 network in Romania followed the same non-systematic

90 approach. The process started in 2007 with designating 273 Sites of Community Importance

91 covering Habitats Directive. This process continues in the present; nowadays, there are 606

92 designated Natura 2000 sites (Sites of Community Importance and Special Protection Areas) that

93 encompass 23% of the total country's land area (54214 km^2) (DG Environment 2020; Manolache

94 et al. 2017). Of these, 426 are terrestrial Natura 2000 Sites of Community Importance, covering

95 40310 km^2 (17% of Romania's terrestrial surface) (DG Environment 2020; EIONET 2020).

96 During the first two designation stages, the process was highly biased towards overlapping

97 existing national protected areas (Iojă et al. 2010; Manolache et al. 2017), and thus, even if the

98 CBD 17% target is met, the effectiveness of Natura 2000 in representing habitats and species is

99 questionable. For example, Iojă et al. (2010) confirmed that overlapping existing national

100 protected areas resulted in a suboptimal representation of plants and invertebrates; Miu et al.

101 (2018) highlighted underrepresentation of agricultural landscape in Dobrogea, while Mânzu et al.

102 (2013) and Popescu et al. (2013) concluded that the Natura 2000 network would not protect

103 plants, reptiles, or amphibians if species ranges shift under climate change scenarios.

104 With the latest extensions, the Romanian Natura 2000 network encompasses all species and

105 habitats listed in Habitats and Birds Directives (DG Environment 2020; Manolache et al. 2017);

106 however, the new EU Biodiversity Strategy for 2030 requires an increase from 23% to 30% of

107 the total terrestrial country's area of which one third should be under strict protection as areas of

108 very high biodiversity and climate value (European Commission 2020). To help identify areas

109 with very high biodiversity and to provide an example of systematic planning of a protected area

110 network, we present a reproducible spatial prioritization case study using Romania's current
111 terrestrial Natura 2000 network and coarse-scale terrestrial species occurrence (marine Natura
112 2000 sites and species were excluded). The objectives of this study are (1) to identify candidate
113 sites for designation as areas of very high biodiversity within the Romanian terrestrial Natura
114 2000 network in national, taxa-specific and biogeographical levels spatial prioritization scenarios
115 and (2) to investigate the extent to which the areas of very high biodiversity within terrestrial
116 Natura 2000 network cover the species listed in Annex II of Habitats Directive in national, taxa-
117 specific and biogeographical levels spatial prioritization scenarios. The European Union assesses
118 the effectiveness of Natura 2000 network in protecting species and habitats listed in Birds and
119 Habitats Directives at the Member State level but also at the biogeographic level (Evans 2012);
120 thus, we performed the analyses at both administrative levels.

Methods
121

Natura 2000 sites and species
122

123 The dataset used in our planning analysis included 371 terrestrial Natura 2000 Sites of
124 Community Importance (Natura 2000 SCI), designated to protect 164 terrestrial species listed
125 under Annex II of Habitats Directive in Romania. The initial database included 426 Natura 2000
126 SCI and 166 species (EIONET 2020), from which we excluded 7 sites with a small area (<1 km^2,
127 the spatial resolution of our data), 48 terrestrial sites designed only for habitat protection, and 2
128 marine species (the common bottlenose dolphin - *Tursiops truncatus*, and the harbor porpoise -
129 *Phoecena phoecena*) (Data S1). We used only terrestrial sites and species to match the EU
130 commitment to designate by 2030 as strictly protected of one-third of protected areas separately
131 on land and at sea (DG Environment 2020). Of the 164 species protected by this terrestrial
132 Natura 2000 network, 26 are mammals, 6 are reptiles, 6 are amphibians, 26 are fish, 54 are
133 invertebrates, and 46 are plants. The number of species protected within a Natura 2000 site
134 varies between 1 (46 sites protect only one species) and 62 (Iron Gates). The terrestrial sites with
135 the largest number of protected species (>40 species) are Iron Gates, Domogled - Valea Cernei,
136 Calimani - Gurghiu, Danube Delta, Cheile Nerei – Beusnita, Fagaras Mountains, and Tur River.
137 The largest Natura 2000 sites in terms of surface area (>1200 km^2) are Danube Delta, Fagaras
138 Mountains, Frumoasa, Calimani – Gurghiu, and Iron Gates (Rozylowicz et al. 2019).

139   To map species occurrences in terrestrial Natura 2000, we used site-level occurrence data
140   included in the Natura 2000 Standard Data Forms (EIONET 2020). Site-level occurrence records
141   were aggregated at a Universal Traverse Mercator spatial resolution of 1 km² (UTM 1 × 1 km).
142   Thus, if a species was included in the Standard Data Form (recorded for the respective Natura
143   2000 site), each cell of that site was considered as having that species present. We followed this
144   approach due to the absence of finer scale species distribution data in Romania for Natura 2000
145   taxa, which makes species distribution modelling impractical for all Natura 2000 taxa. While the
146   coarse spatial resolution likely overestimates the distribution of several range-restricted taxa,
147   data at protected area level, rather than within protected areas, is currently used for official
148   biogeographical assessments of conservation status of species and habitats in Romania under
149   Article 17 of the Habitats Directive (EIONET 2020). The likely outcome of overestimating the
150   distribution of some species for this prioritization study, which focuses on species-rich areas
151   (Additive Benefit Function algorithm, see section *Priority ranking of terrestrial Natura 2000*
152   *sites*), is that some protected areas may emerge as top priorities despite the fact that some species
153   are occurring only within a relatively small area within those respective protected areas. Thus,
154   the prioritization results should be interpreted as a Natura 2000 site with a certain proportion to
155   be designated as strictly protected areas and not as the exact position of top priority grid cells. As
156   such, this approach closely matches the approach to conservation planning in Romania, which
157   uses species lists to establish protected areas of various sizes and acknowledges that species may
158   only occur in discrete units within a given protected area (EIONET 2020).

159   The Natura 2000 sites and species considered here were further sorted by biogeographic region.
160   Because Romania lies at the geographic center of Europe (Rey et al. 2007), Natura 2000 network
161   overlaps five terrestrial biogeographical regions, out of the nine regions recognized by the
162   European Union, i.e., Alpine, Continental, Pannonian, Steppic and Black Sea (Rozylowicz et al.
163   2019). Due to its small size, the terrestrial part of Black Sea region was merged with the Steppic
164   biogeographic region (Steppic and Black Sea region in our analysis). Of the 164 terrestrial
165   species, 110 are found in the Alpine Biogeographic Region, 143 in the Continental
166   Biogeographic Region, 76 in the Pannonian Biogeographic Region, and 78 in the Steppic and
167   Black Sea Biogeographic Region. Several species were found in 2 or 3 biogeographic regions
168   due to their wide geographic range (e.g., *Bombina bombina, Bombina variegata, Emys*
169   *orbicularis)* or because they inhabit a greater range of habitats (e.g., *Lutra lutra*) (Data S1).

Priority ranking of terrestrial Natura 2000 sites

To identify priority terrestrial Natura 2000 sites for species conservation and to explore these areas adequately representing species included in Annex II of Habitats Directive, we used Zonation v4, a decision-support software tool for spatial conservation planning with Natura 2000 sites as planning units (Lehtomäki & Moilanen 2013; Moilanen 2007). We analyzed three priority ranking scenarios: (1) nationwide, (2) nationwide for several taxonomic groups separately (amphibians, reptiles, mammals, fish, invertebrates and plants), and (3) separately for each biogeographic region across all taxonomic groups (Alpine, Continental, Pannonian, Steppic and the Black Sea biogeographic regions) (Fig. 1). Zonation produces a priority ranking by iteratively removing planning units (Natura 2000 sites in our case) with the lowest total marginal loss of conservation value while accounting for total and remaining distributions of protected species (Moilanen et al. 2014). Priority ranking starts from the full Natura 2000 network, and the planning units are iteratively removed until there are none remaining. Least valuable sites (e.g., low species richness) are removed first, while the valuable sites (e.g., high species richness) are kept until the end (Di Minin et al. 2014).

Zonation provides four cell removal rules (Core-area Zonation, Additive benefit function, Target-based planning and Generalized benefit function). For our case study, we used additive benefit function with exponent $z = 0.25$ (the default value for species sensitivity to habitat loss), a cell removal rule with a summation structure (Moilanen et al. 2014; Moilanen 2007; Moilanen et al. 2005), which gives higher priority to planning units with a higher number of species present and tended to remove biodiversity-poor cells even if they include rare species. Thus, planning with additive benefit function may result in a selection of top priority areas that have higher performance on average, but retains a lower minimum proportion of original distributions for rare species (Arponen et al. 2005; Moilanen et al. 2014). The additive benefit function fits well to our prioritization objective – identification of high biodiversity value protected areas within the Romanian terrestrial Natura 2000 network.

The outputs of the priority analyses provide the ranking of grid cells within Natura 2000 sites according to their contribution in covering protected species (0 = cells with the lowest priority; 1 = cells with the highest priority). The ranking scores exhibit a uniform distribution; thus, the top spatial conservation priorities (e.g., top 33% of the Natura 2000 network) have a Zonation

200 ranking of ≥0.67. The ranking maps are paired with the performance curves that describe the

201 extent to which each species is retained in any given high-priority or low-priority fraction of the

202 Natura 2000 network (Moilanen et al. 2005; Moilanen et al. 2011). Because we used Natura

203 2000 as a planning unit layer, our analysis can be used to infer how much of a Natura 2000 site

204 should be designated as strictly protected in order to reach one third objective at network level.

Results

Prioritization of Natura 2000 sites at the national level

207 Terrestrial Natura 2000 sites represented as 1×1 km grid cells cover 48954 cells (20.24% of

208 Romanian territory), of which 4920 overlaps less than 5% with the respective protected area. The

209 Natura 2000 sites with high priority grid cells extend over the Carpathians and Transylvania

210 (Fig. 2). Outside of Carpathians (Eastern and Southern Romania), the top-priority Natura 2000

211 sites were principally located along river corridors. The sites with the largest number of grid cells

212 labeled as priority for conservation (> 400 km^2) are Sighisoara Tarnava Mare, Muntii Ciucului,

213 Trascau, Valea Izei si Dealul Solovan, Muntele Ses, Retezat, Podisul Lipovei Poiana Rusca,

214 Dealurile Tarnavei Mici Biches, Semenic Cheile Carasului. A notable exception is the Natura

215 2000 overlapping the lower course of Ialomita river in Eastern Romania (Fig. 2, Data S2).

216 Top-priority sites in national level scenario cover 37% of Natura 2000 protected grid cells in

217 Alpine biogeographic region, 28% of protected grid cells in Continental biogeographic region,

218 22% in Pannonian biogeographic region, and 12% Natura 2000 protected grid cells in the

219 Steppic and the Black Sea biogeographic region (Fig. 2, Data S2).

220 The performance of national-level planning of top priorities is minimal. On average, when 33%

221 of landscape of Natura 2000 sites is protected, only 20% of distribution of species listed in

222 Annex II of Habitats Directive are protected (Fig. S1). As a consequence, the representation of

223 species by priority terrestrial Natura 2000 sites is lessened when compared to the initial set of

224 species, with 20 species (12%) not covered by the top 33% of protected grid cells. The missed

225 species include plants (12 species), invertebrates (4 species), fish (2 species) and mammals (2

226 species) (Table 1, Data S3).

Prioritization of Natura 2000 sites at national level by taxonomic group

228   When priority ranking maps are organized by taxonomic group, the top-priority sites are

229   dissimilar to the results of national level prioritization (Fig. 3). For amphibians, the ranking map

230   (Fig. 3B) indicates that sites with high priority grid cells for conservation are spatially grouped in

231   the western and central parts of Romania, while for reptiles, the sites were clustered in the

232   southwestern and southeastern part of Romania (Fig. 3B). For mammals and plants, most of the

233   high-priority sites are spatially grouped in the Carpathians and Dobrogea areas, regions with

234   large protected areas and high species richness. High priority Natura 2000 sites for invertebrates

235   and fish are dispersed within the country (Fig. 3C-F).

236   The performance of top-priority Natura 2000 sites in representing species distribution varies by

237   taxonomic group (Fig. S2). For invertebrates, the prioritization ranking indicates that if the top

238   33% of the landscape included in Natura 2000 sites is strictly protected, on average only 20% of

239   the invertebrate distributions in Natura 2000 are also protected; this is followed by the amphibian

240   group, with over 50% of the amphibian distribution in Natura 2000 protected. For reptiles,

241   Natura 2000 performs better, with over 90% of the distribution of reptiles in strictly protected

242   areas. For mammals, fish, and plants, the Romanian Natura 2000 network performs very well,

243   with more than 75% of distribution of the respective species strictly protected when the

244   identified top priority 33% of Natura 2000 area is protected.

245   **Prioritization of Natura 2000 sites at biogeographical level**

246   Within the Alpine biogeographic region, the high-priority areas are in Western Carpathians

247   (Natura 2000 sites overlapping Trascau and Apuseni Mountains), Southern Carpathians (Natura

248   2000 sites overlapping Retezat, Domogled, Cerna, Cozia Mountains), and Eastern Carpathians

249   (Natura 2000 sites overlapping Maramures and Gurghiu Mountains) (Fig. 4A, Data S2). Within

250   the Continental biogeographic region, the main high-priority areas overlap Natura 2000 sites in

251   Iron Gates, Semenic, Cheile Nerei (SW Romania), Sighisoara Tarnava Mare (center of

252   Romania), Dealurile Clujului de Est (center of Romania), Tur River (northwest of Romania), and

253   Ciuperceni - Desa (south) (Fig. 4B, Data S2). In the Pannonian biogeographic region, the main

254   high-priority area is in the Lower Mures Floodplain and Carei Plain (western part of Romania)

255   (Fig. 4C, Data S2). In the Steppic and terrestrial Black Sea biogeographic regions, the high-

256   priority areas are North-Dobrogea Tableland, Macin Mountains, Canaralele Dunarii, and Padurea

257   si Valea Canaraua Fetii – Iortmac and Lower Siret Floodplain Natura 2000 (Fig. 4D, Data S2).

258 The performance of Natura 2000 by biogeographical region is similar for Alpine, Steppic-
259 Terrestrial Black Sea and Pannonian. In these regions, when the top 33% of the respective region
260 is strictly protected, between 55% and 65% of the distribution of covered species is strictly
261 protected. The Continental biogeographic region performs better when considering that 33% of
262 landscape of Natura 2000 sites are strictly protected; nearly 75% of the distribution of species
263 listed in Annex II of HD are strictly protected (Fig. S3).

264 The biogeographic level planning scenario produced fewer gap species (i.e., not covered within
265 the strictly protected area network) than the national level scenario when selecting top priorities
266 (Fig. 5, Data S3). Out of 118 species included in Alpine biogeographic region, 9 are gap species
267 if planning is done at the national level and 3 if planning is done at the biogeographical level. Of
268 149 species in Continental biogeographic region, 37 are gap species when prioritization is done
269 at the national level and 6 when it is done at the biogeographical level. Furthermore, out of 75
270 species represented in Pannonian biogeographic region, 27 are gap species in national-level
271 scenarios and only 3 in biogeographical level scenarios. Also, the number of gap species is
272 reduced when planning is done at the Steppic and Black Sea biogeographic region level, with no
273 gap species out of 38 in national-level scenarios and only 12 species in biogeographical level
274 scenarios.

Discussion

276 The EU Biodiversity Strategy for 2030 acknowledges that the current network of protected areas,
277 including those under strict protection, is not sufficiently large to safeguard Europe's biodiversity
278 in the face of multiple stressors. To overcome this issue, the European Commission set ambitious
279 conservation objectives for Member States, such as the enlargement of protected areas to at least
280 30% of terrestrial national territory in Europe, of which one-third should be strictly protected
281 (European Commission 2020). To support policymakers in establishing criteria and guidance for
282 meeting the objective of one-third of protected areas under strict protection, we tested three
283 spatial conservation prioritization scenarios using the Romanian terrestrial Natura 2000 network
284 as a case study. Our analyses suggest that selecting strictly protected areas at the European
285 Biogeographical Region level performs better than nationwide or taxa-specific planning
286 scenarios in terms of species representation and spatial evenness of selected sites.

287 The EU Biodiversity Strategy for 2030 outlines key principles designation of areas of very high
288 biodiversity value, such as including carbon-rich ecosystems (old-growth forests, peatlands) or
289 outermost regions. The strategy also stipulates potential planning scenarios, e.g., at EU bio-
290 geographical regions, national level (European Commission 2020). Because the backbone of
291 strictly protected areas will be within the Natura 2000 network, which already covers over 17%
292 of EU land, these areas with high biodiversity value should also ensure the long-term survival of
293 species and habitats listed in Birds and Habitats Directives (Evans 2012), therefore contributing
294 to the implementation of the two Directives by the EU Member States.

295 In the case of Romanian terrestrial protected areas, when spatial conservation prioritization is
296 done at the national level, the top 33% protected grid cells cover, on average, less than 18% of
297 Habitats Directive-listed species occurrences within the existing Natura 2000 (see Fig. 2, Data
298 S2). The limited coverage of most species indicates that prioritization at a national level is
299 insufficient to ensure that the favorable conservation status is maintained for most species listed
300 in Habitats Directive. Most species that would not be represented in strictly protected areas are
301 plants; 46 plant species will be strictly protected in areas of less than 10 km^2, which may be
302 sufficient only for some range-restricted species since efficient management requires specific
303 measures such as fencing or manual mowing (Heywood 2019). National-level prioritization will
304 also lead to a lack of representation of endangered mammals, such as the European mink *Mustela*
305 *lutreola* and the marbled polecat *Vormela peregusna*. Under the national level prioritization,
306 most of Natura 2000 sites are located within the Continental biogeographic region (51% of
307 priority areas and 48% of the region). The Alpine biogeographic region, which harbors most of
308 the remaining old-growth forests in the Carpathian Mountains (Veen et al. 2010), had a relatively
309 low contribution to high-value priority areas (27% of Alpine region) (see Data S1). The
310 Continental region, which in this scenario would constitute the backbone of strictly protected
311 areas, include many common species when compared to other biogeographic regions (Gruber et
312 al. 2012; Rozylowicz et al. 2019); thus, rare species inhabiting Alpine, Steppic and the Black Sea
313 regions would not be represented in strictly protected areas without a significant expansion of
314 protected areas network. This finding corroborates previous work that found that more than 50%
315 of sites from Alpine, Steppic, and the Black Sea regions are important for the cohesion of the
316 Natura 2000 network at the national level (Rozylowicz et al. 2019).

317   The limited contribution of the national-level prioritization scenario may be due to the

318   prioritization algorithm selected for this analysis (Additive Benefit Function), which favors

319   Natura 2000 sites with high species richness (Di Minin et al. 2014). Using other removal rules,

320   such as Core-Area Zonation, which strives to provide the best representation for each individual

321   species, would result in better representation of range-restricted species; as a result, Natura 2000

322   sites with a high number of endemic species would be retained as areas of high biodiversity

323   value (Kukkala et al. 2016); however, forests and other important carbon-rich ecosystems would

324   be missed, thus limiting more their contribution to achieve the EU Biodiversity Strategy for 2030

325   of one-third under strict protection objective.

326   Spatial conservation prioritization relies on the quality of species distribution data (Wiersma and

327   Sleep, 2016). Studies typically opt to limit planning exercises to the best available species data

328   set (e.g., Kukkala et al. 2016; D'Amen M et al. 2013); however, drawing conclusions on data-

329   rich taxa likely limits the application of systematic conservation planning at a continental level

330   that consider species across all taxonomic groups (see Jung et. 2020 for a comprehensive global

331   analysis). Our analysis, while coarse, does explore several taxonomic groups (amphibians,

332   reptiles, fish, mammals, invertebrates, plants), thus providing a national-level perspective on

333   protecting many levels of biodiversity. For example, we found a limited value of applying

334   spatial conservation prioritization algorithms at national level by taxonomic group (see Fig. 3,

335   Fig. S2, Data S2). In our taxa specific scenarios, the top 33% priority areas overlap 295 Natura

336   2000 sites, of which 222 sites include priority areas for invertebrates, 92 sites for amphibians, 73

337   sites for plants, 63 sites for fish species, 58 sites for reptiles, and 42 sites for mammals.

338   Achieving the EU Biodiversity Strategy 203 targets will result in overshooting the one-third

339   strictly protected target, and will require significant land availability and funding to implement,

340   neither being a feasible and efficient prerequisite to conservation in Romania and the EU

341   (Hermoso et al. 2019). Despite their limited value for the EU biodiversity targets, the taxonomic

342   group-based scenarios can be used to identify key areas for a specific taxon and could be used to

343   complement the more realistic, biogeographic regional-based scenarios. This type of

344   prioritization can also be used to understand the data gaps across taxonomic groups. For

345   example, in our case, the top 33% planning units for 53 invertebrate species include 222 Natura

346   2000 sites out of 371, while for 46 plant species, the prioritization algorithm will select planning

347   units for 73 Natura 2000 sites. The large number of sites selected in the top 33% for invertebrates

348 is a direct result of insufficient monitoring efforts for these species, and a lack of taxonomists

349 (Brodie et al. 2019; Cardoso et al. 2011; D'Amen et al. 2013). Data gaps likely resulted in a

350 lower than expected species per site, thus affecting the outcomes of our prioritization exercise.

351 The biogeographical region level prioritization resulted in a balanced distribution of top-priority

352 planning units across the country. This is an expected result, as prioritization using biologically-

353 significant administrative borders will reduce the lower coverage of areas with many range-

354 restricted species (Kukkala et al. 2016). The biogeographic region level planning scenarios also

355 resulted in a smaller number of sites with planning units in top 33%, with 104 Natura 2000 sites

356 when planning region by region (19 sites belong to more than a region) compared to 222 sites

357 under the national level scenario (see Fig. 4, Data S2). Most sites with top-priority grid cells

358 occur in the Continental region (56 sites) and the Alpine region (38 sites), followed by the

359 Steppic and terrestrial Black Sea (23 sites), and the Pannonian regions (8 sites). Biogeographic-

360 focused planning scenarios also performs better in terms of species representation, with only 12

361 species not covered by top-priority planning units (see Data S3, Fig. 5). Only one species is

362 missed by all biogeographic regions - European bison, *Bison bonasus*) - which would require

363 only one new Natura 2000 site for complete representation (e.g., Tarcu Mountains in SW

364 Romania is on of them, and there are ongoing efforts to reintroduce bison in the Southern

365 Carpathians, Fagaras Mountains).

366 Our prioritization is constrained by the limited availability of occurrence data for most of the

367 Annex II Habitats Directive species. With few exceptions, such as reptiles, amphibians,

368 mammals in the Dobrogea region, large carnivores (Bîrsan et al. 2017; Cogălniceanu et al.

369 2013a; Cogălniceanu et al. 2013b; Cristescu et al. 2019; Miu et al. 2018) species distribution data

370 are available as extent of occurrence, rather than specific locations or modeled species

371 distributions (EIONET 2020). Also, other sources extensively used in prioritization research,

372 such as GBIF (e.g., Guo et al. 2020), include low numbers of occurrence data for Romania. To

373 overcome this shortcoming we used Natura 2000 Standard Data Form, the technical

374 documentation of a Natura 2000 which includes species for which it was designated (Lisón et al.

375 2017), and the spatial resolution of data reported by the Romanian authorities for

376 biogeographical assessments of the conservation status of species and habitats under Article 17

377 of the Habitats Directive (EIONET 2020). While this is less than ideal for systematic

378 conservation planning, it showcases the real-world decision-making process in Eastern European

379 conservation. This is why we support the existing calls for obtaining robust species distribution

380 data prior to establishing and planning strictly protected areas, especially for overlooked species

381 such as invertebrates (Cardoso et al. 2011).

Conclusions

383 The EU Biodiversity Strategy for 2030 requires an expansion of protected areas network in

384 Europe, of which one third should be under strict protection as areas of very high biodiversity

385 and climate value. The strategy outlines key principles for designation of strictly protected areas

386 but without providing clear guidelines. To support policymakers in establishing criteria and

387 guidance for meeting the target of one-third of protected areas under strict protection, we provide

388 here a reproducible spatial prioritization case study using Romania's current terrestrial Natura

389 2000 network and coarse-scale terrestrial species occurrence. Our results indicate that

390 designation of strictly protected areas using a systematic conservation planning approach at

391 biogeographic region-level would result not only in a good representation of all species protected

392 by EU legislation in a country but also in spatial evenness of selected sites. The species-specific

393 approach used in our example may be easily expanded to include other dimensions of

394 biodiversity, such as carbon-rich areas and old-growth forests, ecological corridors, etc.

395 However, because the results are dependent no only on setting clear targets but also on data

396 quality, we urge policymakers to invest in producing high-quality biodiversity data before

397 proceeding to the designation of new areas of strict protection.

Acknowledgments

399 We thank the two reviewers for comments and suggestions and Edward F. Rozylowicz for

400 proofreading and suggestions, which helped us to improve the quality of the manuscript.

References

402 Apostolopoulou E, and Pantis JD. 2009. Conceptual gaps in the national strategy for the

403   implementation of the European Natura 2000 conservation policy in Greece. *Biological*

404   *Conservation* 142:221-237. 10.1016/j.biocon.2008.10.021

405 Araújo MB, Alagador D, Cabeza M, Nogués-Bravo D, and Thuiller W. 2011. Climate change

406   threatens European conservation areas. *Ecology Letters* 14:484-492. 10.1111/j.1461-

407   0248.2011.01610.x

408 Arponen A, Heikkinen RK, Thomas CD, and Moilanen A. 2005. The value of biodiversity in
409   reserve selection: Representation, species weighting, and benefit functions. *Conservation*
410   *Biology* 19:2009-2014. 10.1111/j.1523-1739.2005.00218.x

411 Bîrsan C, Iosif R, Szekely P, and Cogălniceanu D. 2017. Spatio-temporal Bias in the Perceived
412   Distribution of the European Pond Turtle, Emys orbicularis (Linnaeus, 1758), in
413   Romania. *Acta Zoologica Bulgarica* 10:37–41.

414 Brodie BS, Popescu VD, Iosif R, Ciocanea C, Manolache S, Vanau G, Gavrilidis AA, Serafim R,
415   and Rozylowicz L. 2019. Non-lethal monitoring of longicorn beetle communities using
416   generic pheromone lures and occupancy models. *Ecological Indicators* 101:330-340.
417   10.1016/j.ecolind.2019.01.038

418 Cardoso P, Erwin TL, Borges PA, and New TR. 2011. The seven impediments in invertebrate
419   conservation and how to overcome them. *Biological Conservation* 144:2647-2655 DOI:
420   10.1016/j.biocon.2011.07.024

421 Cogălniceanu D, Rozylowicz L, Székely P, Samoilă C, Stănescu F, Tudor M, Székely D, and
422   Iosif R. 2013a. Diversity and distribution of reptiles in Romania. *ZooKeys* 341:49-76
423   DOI: 10.3897/zookeys.341.5502

424 Cogălniceanu D, Székely P, Samoilă C, Iosif R, Tudor M, Plăiaşu R, Stănescu F, and
425   Rozylowicz L. 2013b. Diversity and distribution of amphibians in Romania. *ZooKeys*
426   296:35-57 DOI: 10.3897/zookeys.296.4872

427 Council Directive 92/43/EEC. Council Directive 92/43/EEC of 21 May 1992 on the conservation
428   of natural habitats and of wild fauna and flora. Available at https://eur-
429   lex.europa.eu/legal-content/EN/TXT/?uri=celex:31992L0043 (accessed 24 August 2020).

430 Cristescu B, Domokos C, Teichman KJ, and Nielsen SE. 2019. Large carnivore habitat
431   suitability modelling for Romania and associated predictions for protected areas. *PeerJ*
432   7:e6549 DOI: 10.7717/peerj.6549

433 D'Amen M, Bombi P, Campanaro A, Zapponi L, Bologna MA, and Mason F. 2013. Protected
434   areas and insect conservation: Questioning the effectiveness of Natura 2000 network for
435   saproxylic beetles in italy. *Animal Conservation* 16:370-378 DOI: 10.1111/acv.12016

436 DG Environment. 2020. Natura 2000 barometer. *Natura 2000 Nature and biodiversity newsletter*
437   47:8-9.

438   Di Minin E, Veach V, Lehtomäki J, Pouzols FP and Moilanen A. 2014. A quick introduction to
439   Zonation. Version 1 (for Zv4). University of Helsinki

440   Dimitrakopoulos PG, Memtsas D, and Troumbis AY. 2004. Questioning the effectiveness of the
441   Natura 2000 Special Areas of Conservation strategy: The case of Crete. *Global Ecology*
442   *and Biogeography* 13:199-207 DOI: 10.1111/j.1466-822X.2004.00086.x

443   Directive 2009/147/EC. Directive 2009/147/EC of the European Parliament and of the Council
444   of 30 November 2009 on the conservation of wild birds. *Available at https://eur-*
445   *lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02009L0147-20190626* (accessed 24
446   August 2020)

447   EIONET. 2020. Central Data Repository. Natura 2000 network (Birds Directive and Habitats
448   Directive).   Natura   2000   updating   2019.   *Available   at*
449   *https://cdr.eionet.europa.eu/ro/eu/n2000/envxdvb_a/* (accessed March, 5 2020).

450   European Commission. 2020. EU Biodiversity Strategy for 2030. Bringing nature back into our
451   lives. Communication from the Commission to the European Parliament, the Council, the
452   European Economic and Social Committee and the Committee of the Regions. *Available*
453   *at   https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0380*
454   (accessed 24 August 2020).

455   Evans D. 2012. Building the European Union's Natura 2000 network. *Nature conservation* 1:11
456   DOI: 10.3897/natureconservation.1.1808

457   Geldmann J, Barnes M, Coad L, Craigie ID, Hockings M, and Burgess ND. 2013. Effectiveness
458   of terrestrial protected areas in reducing habitat loss and population declines. *Biological*
459   *Conservation* 161:230-238 DOI: 10.1016/j.biocon.2013.02.018

460   Gray CL, Hill SLL, Newbold T, Hudson LN, Börger L, Contu S, Hoskins AJ, Ferrier S, Purvis
461   A, and Scharlemann JPW. 2016. Local biodiversity is higher inside than outside
462   terrestrial protected areas worldwide. *Nature Communications* 7:12306 DOI:
463   10.1038/ncomms12306

464   Gruber B, Evans D, Henle K, Bauch B, Schmeller D, Dziock F, Henry P-Y, Lengyel S, Margules
465   C, and Dormann C. 2012. "Mind the gap!"–How well does Natura 2000 cover species of
466   European interest? *Nature conservation* 3:45 DOI: 10.3897/natureconservation.3.3732

467   Guo W-Y, Serra-Diaz JM, Schrodt F, Eiserhardt WL, Maitner BS, Merow C, Violle C, Anand
468   M, Belluau M, Bruun HH, Byun C, Catford JA, Cerabolini BEL, Chacón-Madrigal E,

469   Ciccarelli D, Cornelissen JHC, Dang-Le AT, de Frutos A, Dias AS, Giroldo AB, Guo K,
470   Gutiérrez AG, Hattingh W, He T, Hietz P, Hough-Snee N, Jansen S, Kattge J, Klein T,
471   Komac B, Kraft N, Kramer K, Lavorel S, Lusk CH, Martin AR, Mencuccini M,
472   Michaletz ST, Minden V, Mori AS, Niinemets Ü, Onoda Y, Onstein RE, Peñuelas J,
473   Pillar VD, Pisek J, Robroek BJM, Schamp B, Slot M, Sosinski Ê, Soudzilovskaia NA,
474   Thiffault N, van Bodegom P, van der Plas F, Wright IJ, Xu W-B, Zheng J, Enquist BJ,
475   Svenning J-C. 2020. Half of the world's tree biodiversity is unprotected and is
476   increasingly threatened by human activities. bioRxiv DOI: 10.1101/2020.04.21.052464.

477   Hermoso V, Clavero M, Villero D, and Brotons L. 2017. EU's Conservation Efforts Need More
478   Strategic Investment to Meet Continental Commitments. *Conservation Letters* 10 231-
479   237 DOI: 10.1111/conl.12248

480   Hermoso V, Morán-Ordóñez A, Canessa S, Brotons L. 2019. Realising the potential of Natura
481   2000 to achieve EU conservation goals as 2020 approaches. Scientific Reports 9. DOI:
482   10.1038/s41598-019-52625-4.

483   Heywood VH. 2019. Conserving plants within and beyond protected areas – still problematic
484   and future uncertain. Plant Diversity 41:36–49. DOI: 10.1016/j.pld.2018.10.001.

485   Iojă CI, Pătroescu M, Rozylowicz L, Popescu VD, Vergheleţ M, Zotta M, and Felciuc M. 2010.
486   The efficacy of Romania's protected areas network in conserving biodiversity. *Biological
487   Conservation* 143:2468-2476 DOI: 10.1016/j.biocon.2010.06.013

488   Jung M, Arnell A, de Lamo X, García-Rangel S, Lewis M, Mark J, Merow C, Miles L, Ondo I,
489   Pironon S, Ravilious C, Rivers M, Schepashenko D, Tallowin O, van Soesbergen A,
490   Govaerts R, Boyle BL, Enquist BJ, Feng X, Gallagher RV, Maitner B, Meiri S, Mulligan
491   M, Ofer G, Hanson JO, Jetz W, Di Marco M, McGowan J, Rinnan DS, Sachs JD, Lesiv
492   M, Adams V, Andrew SC, Burger JR, Hannah L, Marquet PA, McCarthy JK, Morueta-
493   Holme N, Newman EA, Park DS, Roehrdanz PR, Svenning JC, Violle C, Wieringa JJ,
494   Wynne G, Fritz S, Strassburg BBN, Obersteiner M, Kapos V, Burgess N, Schmidt-Traub
495   G and Visconti P. 2020. Areas of global importance for terrestrial biodiversity, carbon,
496   and water. bioRxiv. DOI: 10.1101/2020.04.16.021444.

497 Kenig-Witkowska MM. 2017. Natura 2000-The European Union Mechanism for Nature
498   Conservation: Some Legal Issues. *Journal of Comparative Urban Law and Policy* 2:198-
499   214.

500 Kukkala AS, Arponen A, Maiorano L, Moilanen A, Thuiller W, Toivonen T, Zupan L, Brotons
501   L, and Cabeza M. 2016. Matches and mismatches between national and EU-wide
502   priorities: Examining the Natura 2000 network in vertebrate species conservation.
503   *Biological Conservation* 198:193-201 DOI: 10.1016/j.biocon.2016.04.016

504 Lehtomäki J, and Moilanen A. 2013. Methods and workflow for spatial conservation
505   prioritization using Zonation. *Environmental Modelling and Software* 47:128-137 DOI:
506   10.1016/j.envsoft.2013.05.001

507 Lisón F, Altamirano A, Field R, and Jones G. 2017. Conservation on the blink: Deficient
508   technical reports threaten conservation in the Natura 2000 network. *Biological*
509   *Conservation* 209:11-16 DOI: 10.1016/j.biocon.2017.02.003

510 Lisón F, Palazón JA, and Calvo JF. 2013. Effectiveness of the Natura 2000 Network for the
511   conservation of cave-dwelling bats in a Mediterranean region. *Animal Conservation*
512   16:528-537 DOI: 10.1111/acv.12025

513 Manolache S, Ciocanea CM, Rozylowicz L, and Nita A. 2017. Natura 2000 in Romania–a
514   decade of governance challenges. *European Journal of Geography* 8:24-34.

515 Mânzu C, Gherghel I, Zamfirescu Ş, Zamfirescu O, Roşca I, and Strugariu A. 2013. Current and
516   future potential distribution of glacial relict Ligularia sibirica (Asteraceae) in Romania
517   and temporal contribution of Natura 2000 to protect the species in light of global change.
518   *Carpathian Journal of Earth and Environmental Sciences* 8:77-87.

519 Margules CR, and Pressey RL. 2000. Systematic conservation planning. *Nature* 405:243-253
520   DOI: 10.1038/35012251

521 Mikkonen N, and Moilanen A. 2013. Identification of top priority areas and management
522   landscapes from a national Natura 2000 network. *Environmental science & policy* 27:11-
523   20 DOI: 10.1016/j.envsci.2012.10.022

524 Miu IV, Chisamera GB, Popescu VD, Iosif R, Nita A, Manolache S, Gavril VD, Cobzaru I, and
525   Rozylowicz L. 2018. Conservation priorities for terrestrial mammals in Dobrogea
526   Region, Romania. *ZooKeys* 158:133-158 DOI: 10.3897/zookeys.792.25314

527 Moilanen A, Franco AMA, Early RI, Fox R, Wintle B, and Thomas CD. 2005. Prioritizing
528   multiple-use landscapes for conservation : methods for large multi-species planning
529   problems. 57:1885-1891 DOI: 10.1098/rspb.2005.3164

530 Moilanen A, Leathwick JR, and Quinn JM. 2011. Spatial prioritization of conservation
531   management. *Conservation Letters* 4:383-393 DOI: 10.1111/j.1755-263X.2011.00190.x

532 Moilanen A, Pouzols FM, Meller L, Veach V, Arponen A, Leppänen J, and Kujala H. 2014.
533   Spatial conservation planning methods and software ZONATION. User Manual.
534   DOI:10.1017/CBO9781107415324.004

535 Moilanen A. 2007. Landscape Zonation, benefit functions and target-based planning: Unifying
536   reserve selection strategies. *Biological Conservation* 134:571-579 DOI:
537   10.1016/j.biocon.2006.09.008

538 Müller A, Schneider UA, and Jantke K. 2018. Is large good enough? Evaluating and improving
539   representation of ecoregions and habitat types in the European Union's protected area
540   network Natura 2000. *Biological Conservation* 227:292-300 DOI:
541   10.1016/j.biocon.2018.09.024

542 Müller A, Schneider UA, and Jantke K. 2020. Evaluating and expanding the European Union's
543   protected-area network toward potential post-2020 coverage targets. *Conservation
544   Biology* 34:654-665 DOI: 10.1111/cobi.13479

545 Nita A, Rozylowicz L, Manolache S, Ciocănea MC, Miu VI, and Popescu DV. 2016.
546   Collaboration Networks in Applied Conservation Projects across Europe. *Plos One* 11:
547   e0164503:1-16 DOI: 10.1371/journal.pone.0164503

548 Orlikowska EH, Roberge JM, Blicharska M, and Mikusiński G. 2016. Gaps in ecological
549   research on the world's largest internationally coordinated network of protected areas: A
550   review of Natura 2000. *Biological Conservation* 200:216-227 DOI:
551   10.1016/j.biocon.2016.06.015

552 Popescu VD, Rozylowicz L, Cogălniceanu D, Niculae IM, and Cucu AL. 2013. Moving into
553   Protected Areas? Setting Conservation Priorities for Romanian Reptiles and Amphibians
554   at Risk from Climate Change. *PLoS ONE* 8:e79330. DOI: 10.1371/journal.pone.0079330

555 Possingham HP, Wilson KA, Andelman SJ, and Vynme CH. 2006. Protected Areas: Goals,
556   Limitations, and Design. In: Groom MJ, Meffe GK, Carroll RC ed. Principles of
557   Conservation Biology. Boston: Sinauer Associates, 509-533.

558   Pressey RL, Cabeza M, Watts ME, Cowling RM, and Wilson KA. 2007. Conservation planning
559   in a changing world. *Trends in ecology & evolution* 22:583-592. DOI:
560   10.1016/j.tree.2007.10.001

561   Rey V, Ianos I, Groza O, and Patroescu M. 2007. *Atlas de la Roumanie. Nouvelle edition*.
562   Montpellier: Reclus.

563   Rodrigues ASL, Andelman SJ, Bakarr MI, Boitani L, Brooks TM, Cowling RM, Fishpool LDC,
564   Da Fonseca GAB, Gaston KJ, Hoffmann M, Long JS, Marquet PA, Pilgrim JD, Pressey
565   RL, Schipper J, Sechrest W, Stuart SN, Underhill LG, Waller RW, Watts MEJ, and Yan
566   X. 2004. Effectiveness of the global protected area network in representing species
567   diversity. *Nature* 428:640-643. DOI: 10.1038/nature02422

568   Rozylowicz L, Nita A, Manolache S, Popescu VD, and Hartel T. 2019. Navigating protected
569   areas networks for improving diffusion of conservation practices. *Journal of
570   Environmental Management* 230:413-421. DOI: 10.1016/j.jenvman.2018.09.088

571   UNEP. 2011. Strategic Plan for Biodiversity 2011–2020: Further Information Related to the
572   Technical Rationale for the Aichi Biodiversity Targets, Including Potential Indicators and
573   Milestones. New York: UNEP.

574   Veen P, Fanta J, Raev I, Biriş I-A, de Smidt J, Maes B. 2010. Virgin forests in Romania and
575   Bulgaria: results of two national inventory projects and their implications for protection.
576   Biodiversity and Conservation 19:1805–1819. DOI: 10.1007/s10531-010-9804-2.

577   Votsi NEP, Zomeni MS, and Pantis JD. 2016. Evaluating the Effectiveness of Natura 2000
578   Network for Wolf Conservation: A Case-Study in Greece. *Environmental Management*
579   57:257-270. DOI: 10.1007/s00267-015-0621-y

580   Wiersma YF, Sleep DJH. 2016. A review of applications of the six-step method of systematic
581   conservation planning. The Forestry Chronicle 92:322–335. DOI: 10.5558/tfc2016-059.

Representation of protected species by Natura 2000 sites with grid cells selected as high priority in national level prioritization scenario (gap and most represented species).

Taxonomic group	Species	Number of top 33 % Natura 2000 sites covering the species
Plants	*Centaurea jankae, Potentilla emilii-popii, Centaurea pontica, Dracocephalum austriacum, Ferula sadleriana, Gladiolus palustris, Stipa danubialis, Thlaspi jankae, Tulipa hungarica, Paeonia officinalis* subsp. *banatica, Colchicum arenarium, Saxifraga hirculus*	0
	Ligularia sibirica	17
Invertebrates	*Graphoderus bilineatus, Stenobothrus eurasius, Isophya harzi, Vertigo moulinsiana*	0
	Lucanus cervus	41
Fish	*Cobitis elongata, Rutilus pigus*	0
	Barbus meridionalis	62
Amphibians	-	0
	Bombina variegata	108
Reptiles	-	0
	Emys orbicularis	24
Mammals	*Mustela lutreola, Rhinolophus mehelyi*	0
	Lutra lutra	110

Figure 1

Flowchart illustrating the spatial prioritization process (national, taxa-specific and biogeographical levels spatial prioritization scenarios).
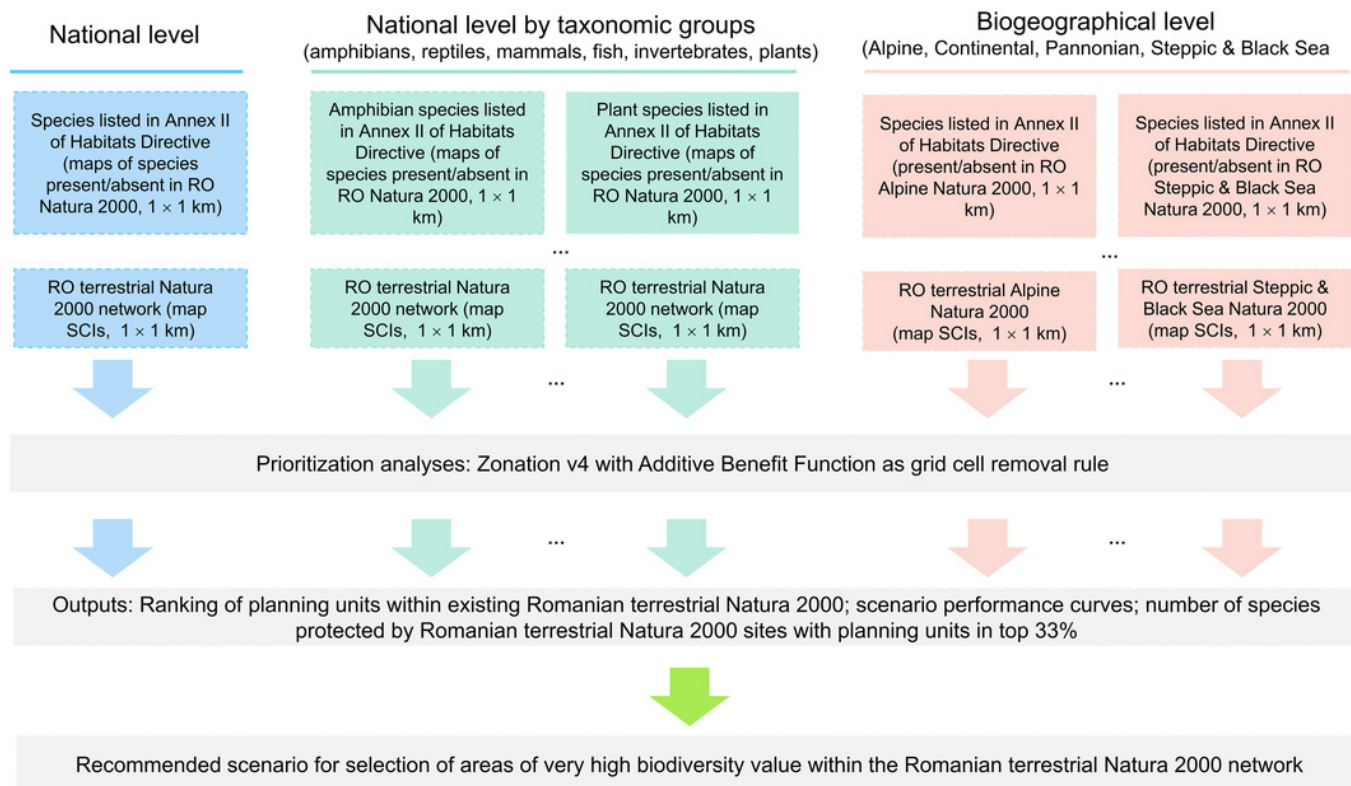
Figure 2

High priority sites for designation as areas under strict protection (national level prioritization scenario).

Grid cells within the Romanian terrestrial Natura 2000 network have been graded according to their priority, with the highest-priority sites (top 33%) shown in red. Biogeographic regions are numbered as follows: I (Alpine), II (Continental), III (Pannonian), IV (Steppic and terrestrial Black Sea).
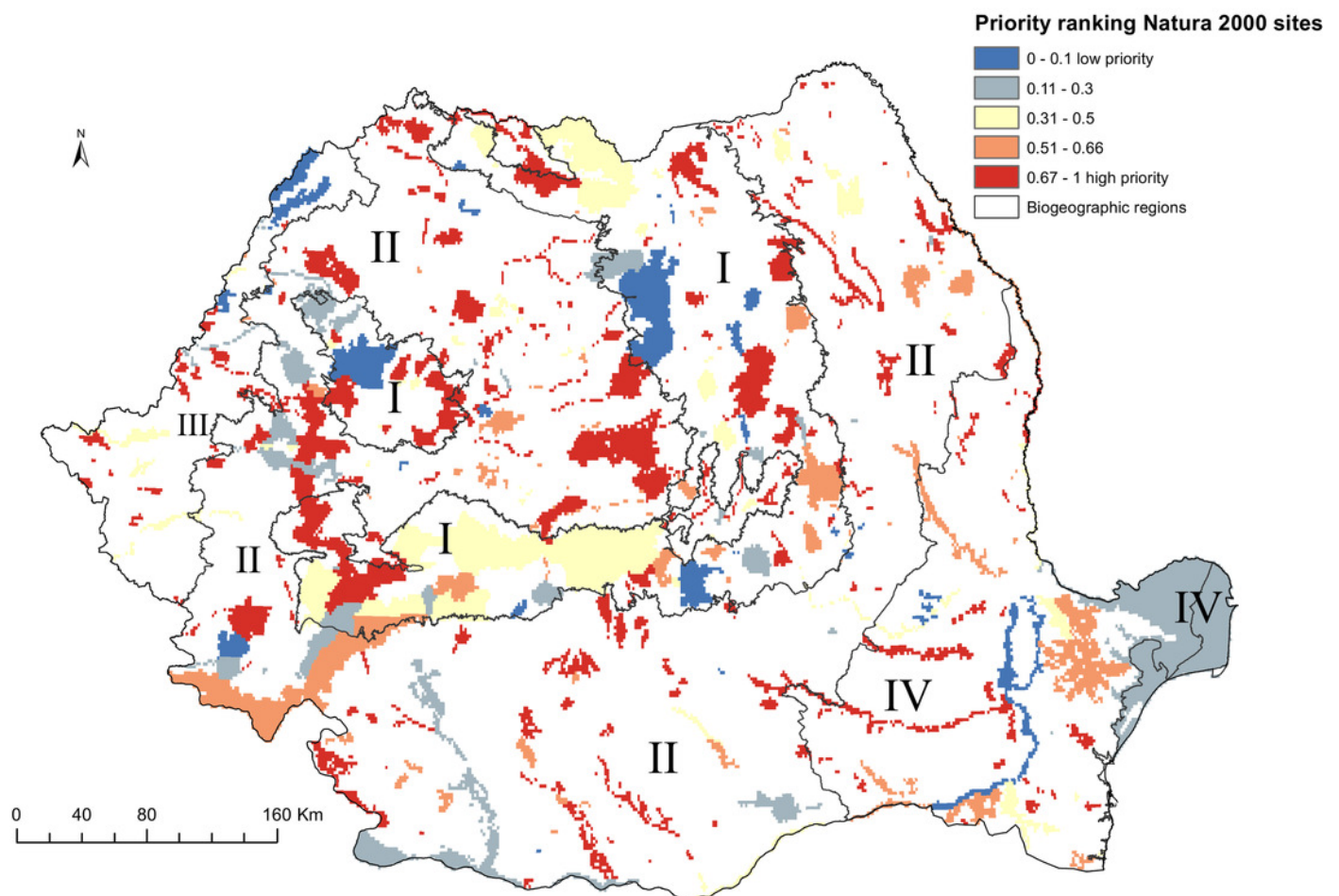
Figure 3

High priority sites for designation as areas under strict protection (taxonomic level prioritization scenario).

Grid cells within the Romanian terrestrial Natura 2000 network have been graded according to their priority, with the highest-priority sites (top 33%) shown in red. Biogeographic regions are numbered as follows: I (Alpine), II (Continental), III (Pannonian), IV (Steppic and terrestrial Black Sea). (A) Amphibians. (B) Reptiles. (C) Invertebrates. (D) Fish. (E) Mammals. (F) Plants.
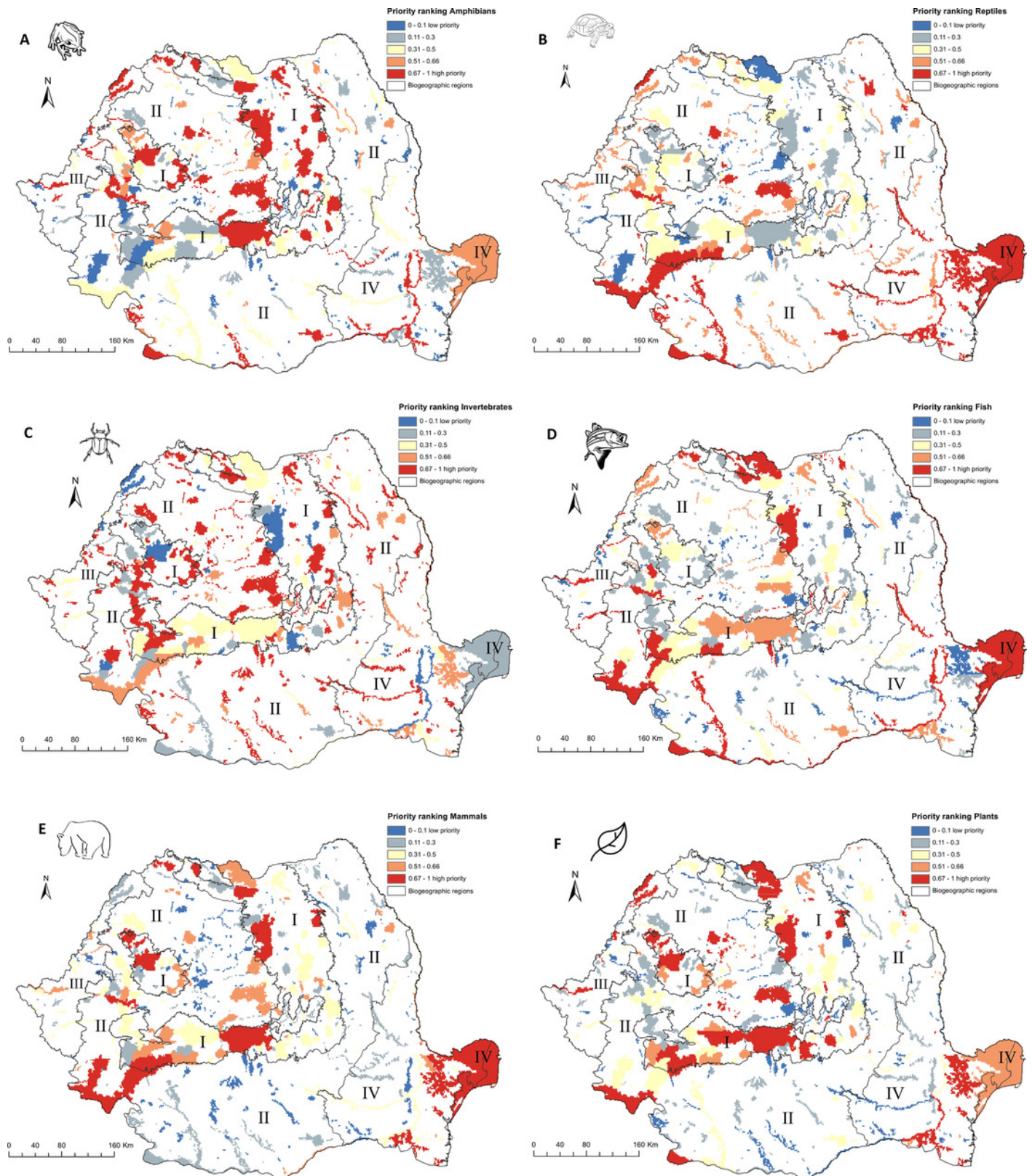
Figure 4

High priority sites for designation as areas under strict protection (biogeographical level prioritization scenario).

Grid cells within the Romanian terrestrial Natura 2000 network have been graded according to their priority, with the highest-priority sites (top 33%) shown in red. (A) Alpine biogeographic region. (B) Continental biogeographic region. (C) Pannonian biogeographic region. (D) Steppic and terrestrial Black Sea biogeographic region.
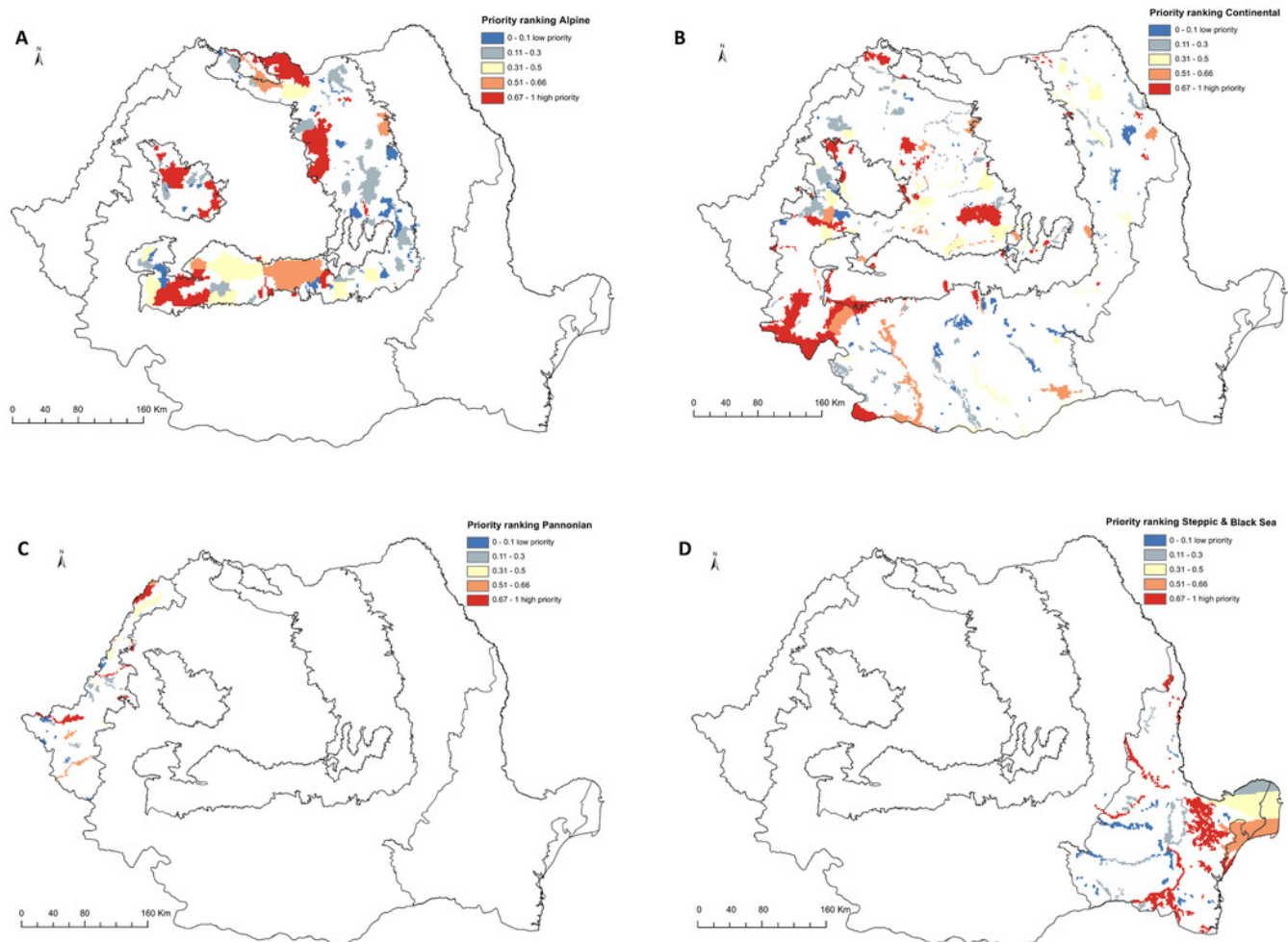
Figure 5

Species representation in the top 33% planning units by prioritization scenarios.

Red = gap species (never included in Natura 2000 sites with high priority grid cells in the respective scenario), Blue = covered species (included in Natura 2000 sites with high priority grid cells in the respective scenario). RO = national level scenario. ALP RO = Alpine EBR in national level scenario. ALP BR = Alpine EBR in biogeographical level scenario; CON RO = Continental EBR in national level scenario. CON BR = Continental EBR in biogeographical level scenario; PAN RO = Pannonian EBR in national level scenario. PAN BR = Pannonian EBR in biogeographical level scenario; STE RO = Steppic and terrestrial Black Sea EBR in national level scenario. STE BR = Steppic and terrestrial Black Sea EBR in biogeographical level scenario.