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ORIGINAL RESEARCH

Analysing the distribution of strictly protected areas toward the EU2030 target

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Abstract

Protecting global biodiversity is one of the most urgent tasks for the coming decades. Area-based conservation is a pillar for preserving ecosystems and species. Strictly protected areas specifically preserve biodiversity and ecosystem processes. The "EU Biodiversity Strategy for 2030" targets strict protection for 10% of land area. Here we performed the first analysis of strictly protected areas (as IUCN type Ia, Ib, and II) across Europe, by investigating their area coverage at the level of biogeographical regions, countries and elevation gradients. We show that, with few exceptions, the amount of strictly protected area is very limited and the spatial distribution of such protected areas is biased towards higher elevation sites, as in the case of other protected areas. Then, we suggest that potential areas should be identified to expand strictly protected areas with low economic and social costs including, for instance, areas with high biodiversity value, low population, and low productive land use. Finally, we propose that a coordinated effort and a strategic plan to achieve continental-scale conservation are fundamental, and at least half of this land under strict conservation (i.e. 5%) should be under the protection categories Ia and Ib.

Keywords Biodiversity goals · EU2030 · Protected Areas · Strict conservation · Natura 2000

Introduction

The destruction, degradation, and fragmentation of habitats have been identified among the main drivers of biodiversity loss, and are triggering the sixth mass extinction (Barnosky et al. 2011; Titeux et al. 2016; Ceballos & Ehrlich 2018). More than 70% of terrestrial land area (excluding Antarctica) and around 90% of the oceans have been directly modified by human activities (Watson et al. 2018). In Europe, no single contiguous land area > 10,000

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km^2 free of human pressures is left (Watson et al. 2018). However, fragments of areas with high wilderness and slightly altered ecosystems still exist, mostly within protected areas (Potapov et al. 2017; Cazzolla Gatti et al. 2021a, b; Maiorano et al. 2015). These are often surrounded by areas in which habitats and ecological processes have been substantially modified (Fahrig 2003) and are located at medium–high altitudes (Joppa & Pfaff 2009), limiting the protection of the more impacted lowlands (Araújo et al. 2011).

In May 2020, the “EU Biodiversity Strategy for 2030” (hereafter EU BIO-2030), an ambitious plan to protect nature and reverse ecosystem degradation (Mammola et al. 2020; Miu et al. 2020), was signed. According to this strategy, which aims to protect wildlife and to improve society’s resilience against climate change, forest fires, food insecurity, and disease outbreaks, the EU aims to enlarge the protected area network up to 30% of its territory, enforcing strict protection on one-third of this area. This establishes a binding target of strictly protecting 10% of the land and sea surface for all EU countries (European Commission 2020). Ensuring a proportion of the area as a target for strict protection may not be sufficient for ensuring biodiversity conservation, but it is a fundamental element for long-term preservation of ecosystem processes and support high levels of biodiversity persistence (Pimm et al. 2018). A target of 10% of the strictly protected area is an ambitious goal for European countries, whose landscapes have been deeply shaped by millennia of land use and anthropogenic impact. The 10% target of strict protection was identified on the basis of global and European targets to preserve the planetary heritage for future generations, ensuring a high level of wilderness and endangered species protection (Dinerstein et al. 2017; Pimm et al. 2018; Wilson 2016; Butchart et al. 2016).

According to the EU Commission Staff Working Document (EC 2022): “*Strictly protected areas are fully and legally protected areas designated to conserve and/or restore the integrity of biodiversity-rich natural areas with their underlying ecological structure and supporting natural environmental processes. Natural processes are therefore left essentially undisturbed from human pressures and threats to the area’s overall ecological structure and functioning, independently of whether those pressures and threats are located inside or outside the strictly protected area*”. This definition is still not included in the legislation of EU Member States but it gives a clear idea of what should be considered as strictly protected in the EU context. For now, strictly protected areas (hereafter ‘StPA’) can likely be identified as IUCN categories Ia (Nature Reserve), Ib (Wilderness Area), and II (National Park) (IUCN 2022). Within these areas all industrial, extractive, and destructive uses and activities that disturb species and habitats such as mining, mineral extraction, deforestation, aquaculture and construction, etc. are usually not allowed (Edgar et al. 2014; Ferreira et al. 2020; Leberger et al. 2020). There are, however, differences in terms of management across and within these three types of protected areas. These categories of protected areas are effective only when left essentially undisturbed, with only limited and well-controlled activities that do not interfere with natural processes. Management actions may be allowed to sustain or enhance natural processes, as well as restoration or conservation of the habitats and species for whose protection the area has been designated.

Considering that in Europe most of the territory has been profoundly modified by humans, strictly protected areas should also include territories that may recover their biodiversity value through restoration and rewilding (Navarro & Pereira 2012). Thus, in strictly protected areas conservation efforts can aim to protect ecological processes and wilderness areas, as well as to restore degraded ecosystems and recreate areas with a high level of naturalness (Carver et al. 2021). To achieve the goals aimed by the EU 2030 Biodiversity Strategy, it is first needed to designate a sufficient area to be strictly protected, as stated by the EU 10% target. Up to now, biogeographical and ecological analysis of the coverage of strictly protected areas in the EU is lacking, limiting the establishment of broad-scale conservation policies.

To help achieve the EU BIO-2030 targets, we assessed the terrestrial area coverage of StPAs in Europe, across biogeographical regions and countries. Hence, we provided a conservative estimate of the necessary area expansion of StPAs to achieve the 10% target of EU BIO-2030.

Methods

We investigated the distribution of StPAs (IUCN categories Ia—Strict Nature Reserve, Ib—Wilderness Area, and II—National Park) in the area of EU27 countries. We preferred to focus on these three IUCN categories because they best match the definition of what a strictly protected area is and should be in most European countries. In fact, other studies looking at the effectiveness of strictly protected areas in other parts of the world acknowledged that other potentially suitable categories (such as Cat. IV) may be too loose (e.g. designed for multiple use) to be considered strictly protected (Ferraro et al. 2013). This applies to the case of Europe as well.

For data collection, we used the following data sources:

- Common Database on Designated Areas (CDDA; EEA 2021) to identify StPAs,
- the EU27 countries layer from Hijmans et al. (2018),
- the European biogeographical regions layer (EEA 2020a),
- the Natura 2000 layer (EEA 2020c) which represents the EU coordinated network of PAs (i.e. Natura 2000) and only partly corresponds to CDDA,
- the Corine Land Cover 2018 layer (Copernicus 2021a), which categories EU land area in different land covers according to Corine standard,
- the EEA reference grid layer (EEA 2020b) that is a 10 km grid encompassing all EU except for Oversea French Territories,
- the EU27 population density grid layer (Gallego 2010), which seeks to represent 2011 EU population census at 1 km^2, and
- the EU-DEM v.1.1 (Copernicus 2021b), a 25 m resolution digital elevation model covering all EU except for Overseas French Territories.

All layers were retrieved with the ETRS89-extended / LAEA Europe coordinate reference system (EPSG:3035) or were reprojected into it before subsequent processing. We extracted *StPAs* polygons from CDDA, keeping only terrestrial and partly terrestrial protected areas ("Terrestrial" and "Marine and Terrestrial" in the field "majorEcosystemType") and excluding Overseas French Territories. We counted the total number of protected areas and their frequencies across the different IUCN categories. Following this, we rasterized strictly protected areas at 250 m resolution and aligned to that grid. When StPAs with different IUCN categories were found in the same pixel, we kept the strictest one (i.e. Ia > Ib > II). We overlaid biogeographical regions and countries on protected areas, by rasterizing them with the same resolution and extent. As we were interested in terrestrial portions of entirely or only partly terrestrial StPAs, we removed marine portions by masking them using biogeographical regions and countries' rasters. Subsequently, we calculated the total area of StPAs, as well as those of the separate IUCN categories. We also calculated the same metrics across biogeographical regions and countries, as well as the relative share of the various StPAs for each biogeographical region and country.

To analyze the elevational distribution of StPAs across biogeographical regions and countries, we first aggregated the EU-DEM v.1.1 tiles from 25 to 250 m, merged them in a single layer, and overlaid them onto the previously processed layers. Following this, we compared the proportional area distribution along the elevational gradient of the StPAs to the proportional area distribution along the elevational gradient of each biogeographical region and country, by means of Wilcox tests.

We quantified the potentially available area to expand the *StPAs* in EU27 countries to achieve the 10% target. For this analysis, we did not consider the biodiversity value of the sites, but just focused on the amount of area as a first reference value. We assumed that potentially available areas should have low human population densities. We started by removing the existing StPAs. Second, we aggregated the population density grid (people/ km^2) from 100 to 500 m spatial resolution; the population density in each cell with 500 m resolution was obtained by taking the mean value of the 25 smaller grid cells with resolution 100 m. After this procedure, we resampled the population density grid with 500 m cells, generating a new grid with a 250 m resolution, using bilinear interpolation, that exactly overlapped with the other layers. All land areas with population densities higher than the median value of the existing *StPAs* of type II were removed. Subsequently, we removed artificial surfaces and agricultural areas by rasterizing Corine Land Cover polygons with codes starting with 1 or 2 ("Artificial surfaces" and "Agricultural areas", respectively) at 250 m resolution. We analyzed the distribution of the potentially available area across biogeographical regions and countries and added these values to the area of already existing *StPAs* to estimate the feasibility of reaching the 10% target across biogeographical regions and countries.

We also intersected the potentially available area on the polygons of the Natura 2000 sites to identify the overlap with areas which are protected in some measure by EU legislation (the Natura 2000 network) and can correspond to other forms of national or subnational protection (Supplementary Table 4). We excluded the Portuguese islands of the Azores and Madeira from the analysis, because population density data were not available for those areas. Natura 2000 is the largest coordinated network of protected areas in the world, stretching over 18% of the EU's land area and more than 8% of its marine territory and aims to protect Europe's biodiversity (EC 2021). The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under the Birds and Habitats Directives (EC 2021). Natura 2000 is made up of areas under different degrees of protection, with many sites being managed for sustainable use of natural resources (EC 2023). With respect to the IUCN classification, which focuses on the management objectives, the scope of Natura 2000 is conservation in a "satisfactory state" of habitats and species listed in the annexes of the aforementioned directives (EC 2021). The single member states decide the case-by-case conservation measures and different Natura 2000 sites are managed with different approach and can, therefore, be classified under various IUCN categories. For their focus on the conservation of species and habitat combined with the sustainable management of resources, most Natura 2000 sites can be categorised as IUCN category IV (habitat/species management area) or VI (protected area with sustainable use of natural resources). However, some Natura 2000 sites are located inside national parks or strict reserves and therefore can be categorised as IUCN Ia, Ib, or II (Supplementary Table 4).

All analyses were performed and graphical outputs were prepared with R v. 3.6.3 (R Core Team 2021) and the packages *raster* (Hijmans 2020), *RStoolbox* (Leutner, et al.

2019), *tidyverse* (Wickham et al., 2019), *sf* (Gallego 2010), *terra* (Hijmans 2021), *patchwork* (Pedersen 2020), *ggridges* (Wilke 2021), *ggsci* (Xiao 2018) and *scales* (Wickham & Seidel 2020).

Results

We recorded 9,382 *StPAs* with a cumulative area of 139,153.38 km^2, which amounted to 3.37% of the terrestrial area of the EU27 countries. Among them, 7,812 *StPAs* belong to IUCN category Ia (total surface of 11,729.62 km^2, 0.28% of the area), 1,101 are IUCN category Ib (60,476.88 km^2, 1.46%), and 469 are IUCN category II (66,946.88 km^2, 1.62%).

Strictly Protected Areas across countries and biogeographical regions

The cumulative area covered by *StPAs* is low for most of the countries and biogeographical regions (Fig. 1). Luxembourg and Sweden are the only countries that met the 10% target of *StPAs* (Fig. 1). However, for Sweden, while the part of the country in the *Alpine* region was above the target (39.4%), the parts of the country in the *Boreal* and *Continental* regions were below the threshold (3.2% and 0.6%, respectively). All other countries had a cumulative value of *StPAs* < 10%, with a few countries passing the target within some biogeographical regions, such as Finland, Slovenia and Bulgaria in the *Alpine* region (73.6%, 11.2% and 12%, respectively), Spain in the *Macaronesian* region (19.2%), Lithuania in the *Continental* region (84.2%) and Portugal in the *Atlantic* region (10.1%).

The situation across countries was mirrored across biogeographical regions (Fig. 1), with only two regions achieving the 10% target. Overall, only in the *Alpine* region the target is achieved (16.5%) by the high coverage alpine *StPAs* in Sweden, Finland, Slovenia

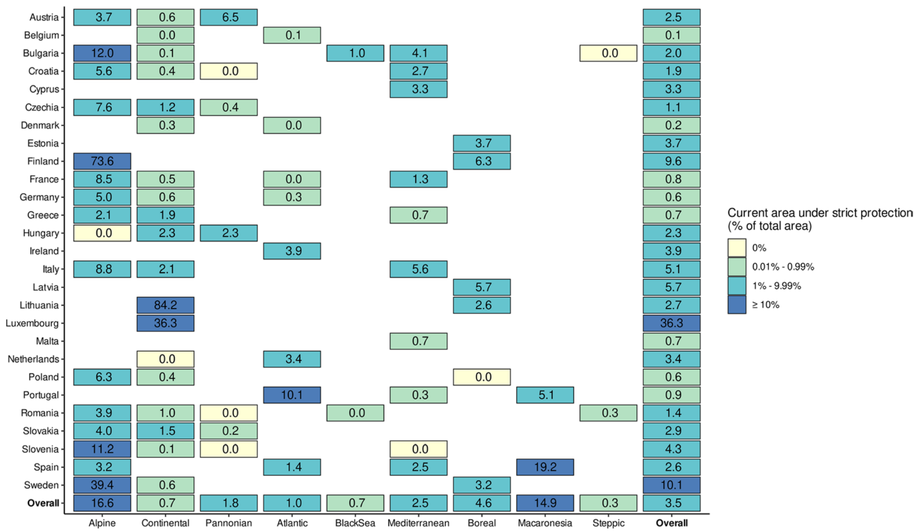

Fig. 1 Proportion of area actually covered by strictly protected areas (IUCN category Ia, Ib and II) across EU27 countries and biogeographical regions

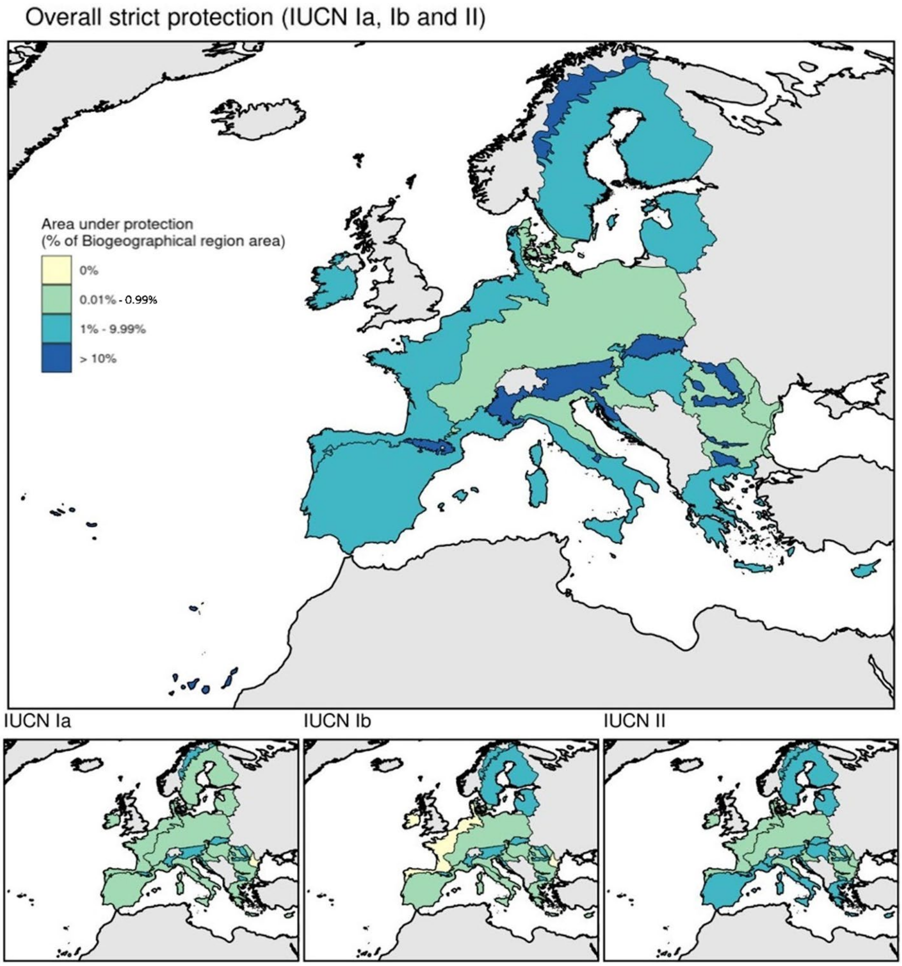

Fig. 2 Area under protection across biogeographical regions for strictly protected areas. Cumulative area under protection (%) for each biogeographical region is shown for all strictly protected areas in the upper panel and for the 3 different IUCN categories (Ia, Ib, and II) in the lower panels

and Bulgaria, while other 12 countries, mostly in the central and southern parts of the alpine region do not currently achieve the 10% target. In the *Macaronesia* region, the target is reached in Spain (19.2%) but not in Portugal (5.2%). All the other biogeographical regions, the *StPA* coverage was far below the 10% target, and in the *Continental*, *Black Sea*, *Atlantic* and *Steppic* regions was even lower than 1%.

Types of STPAs across biogeographical regions and countries

Considering only the strictest categories of protection (IUCN Ia and Ib), the protection level across biogeographical regions was very low for most of the regions (Fig. 2 and Supplementary Table 1). Six out of nine biogeographical regions have a cumulative protection by StPAs of type Ia and Ib of < 1%, with only the *Alpine*, *Boreal* and *Macaronesian* regions

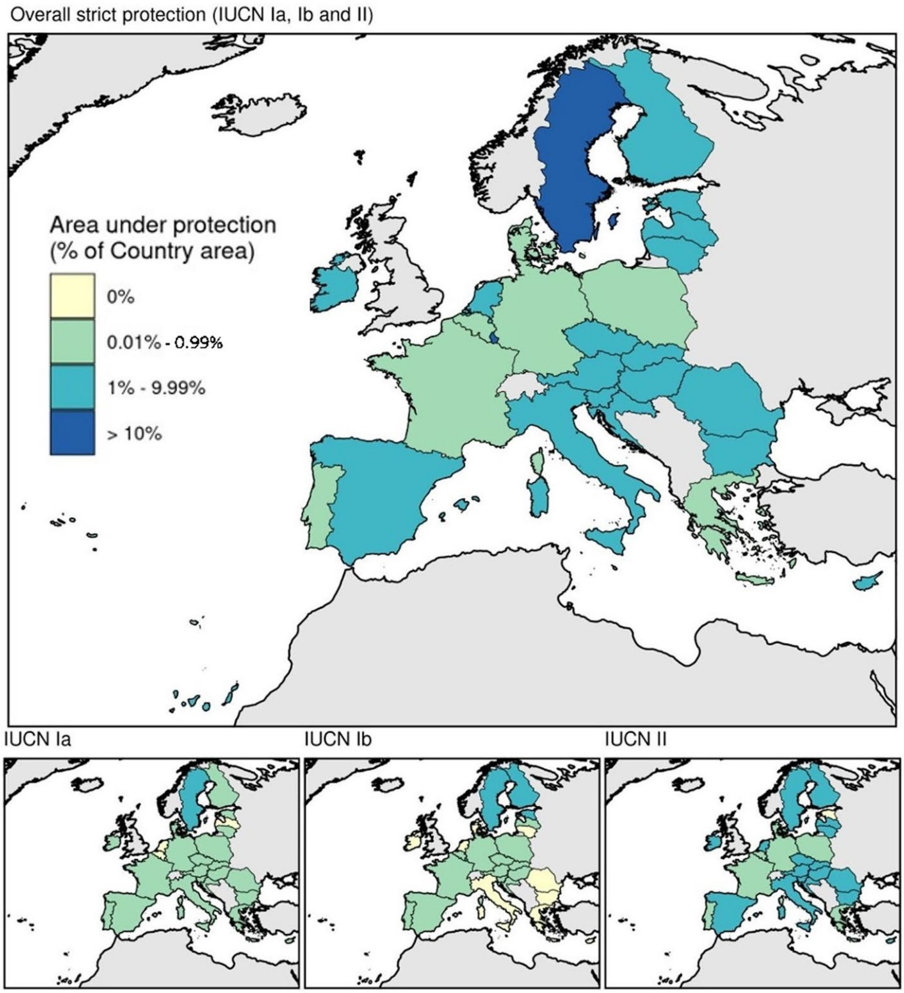

Fig. 3 Area under protection across EU27 countries for strictly protected areas. Cumulative area under protection (%) for each country is shown for all strictly protected areas in the upper panel and for the 3 different IUCN categories (Ia, Ib, and II) in the lower panels

exceeding 1%. The *Steppic* region does not have a single *StPA* of type Ia or Ib (Fig. 2 and Supplementary Table 1). Considering the *StPAs* of type II (Supplementary Table 1), four regions have a coverage < 1% (*Atlantic*, *Black Sea*, *Continental* and *Steppic*) while the other regions have values between 1 and 10%. The contribution of *StPAs* of type II is > 1% in five out of nine biogeographic regions, but only in the *Alpine* region does it reach > 5% (Fig. 2 and Supplementary Table 1).

At the country scale, Sweden, Finland, Estonia, Luxembourg and Slovakia have a cumulative area of *StPAs* of type Ia and Ib > 1%, with the first two countries > 5% (Fig. 3 and Supplementary Table 2). All other countries have values < 1%. Eighteen countries have > 1% of the area protected by StPA of type II and 5 countries (Luxembourg, Latvia,

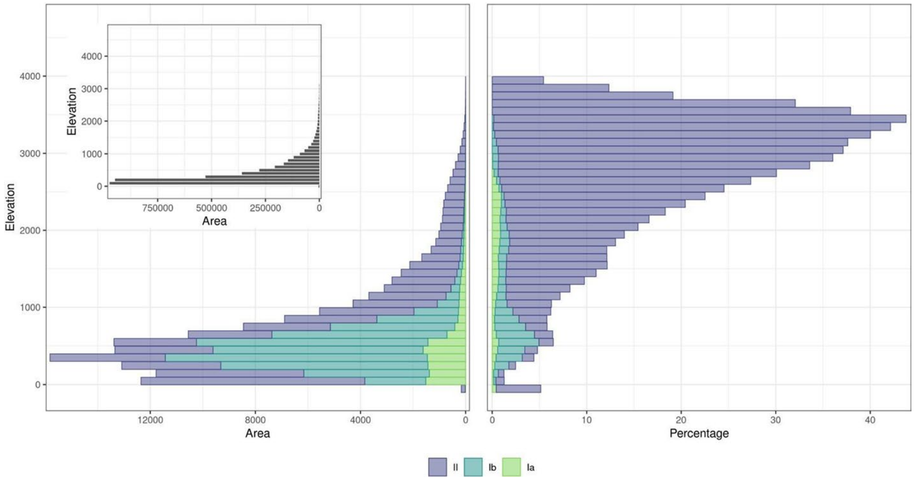

Fig. 4 Distribution of strictly protected areas (IUCN category Ia, Ib and II) across 100 m belts for all EU27. Cumulative area of strictly protected areas is shown in the left panel while the proportion of strictly protected areas with respect to the actual land area is shown in the right panel

Italy, Slovenia, and Netherlands) have > 3% of the area protected by *StPA* of type II (Fig. 3 and Supplementary Table 2).

StPAs across elevational belts

The overall distribution of StPAs across elevational belts showed most protected areas to be below 1000 m a.s.l., but their combined area did not reach the 10% target (Fig. 4). The amount of StPAs is higher than the 10% target only above 1400 m a.s.l. (Fig. 4). Interestingly, most StPAs of type Ib are between 300 and 700 m (Fig. 4). Within biogeographical regions, StPAs show a highly inconsistent distribution with respect to the actual continental elevational range (Fig. 5a), with significant differences between the elevational distributions of the whole biogeographical area and those of the respective protected areas. Examining the StPA categories separately, the elevational distributions also significantly differed from those of the whole biogeographical regions: almost all regions, except the "Alpine", had a low cover by StPAs at lower altitudes, particularly below 300 m (Fig. 5a). A similar picture emerges at the country level, with all the countries showing a significant difference between the elevational distribution of StPAs and the distribution of their elevation range (Fig. 5b). Only Malta and Latvia showed lower differences, yet the deviation is still statistically significant ($p < 0.05$).

Expanding StPAs to reach the 10% target

The analysis of the potentially available area to expand the network of *StPAs* up to the 10% area target (Fig. 6), showed that excellent possibilities exist in the *Alpine*, *Boreal*, *Macaroniesian*, *Black Sea* and *Mediterranean* biogeographical regions, in which almost all the countries have available area with low population density for expanding their *StPAs*. The exceptions include Slovakia in the *Alpine* region, Lithuania in the *Boreal* region, Portugal

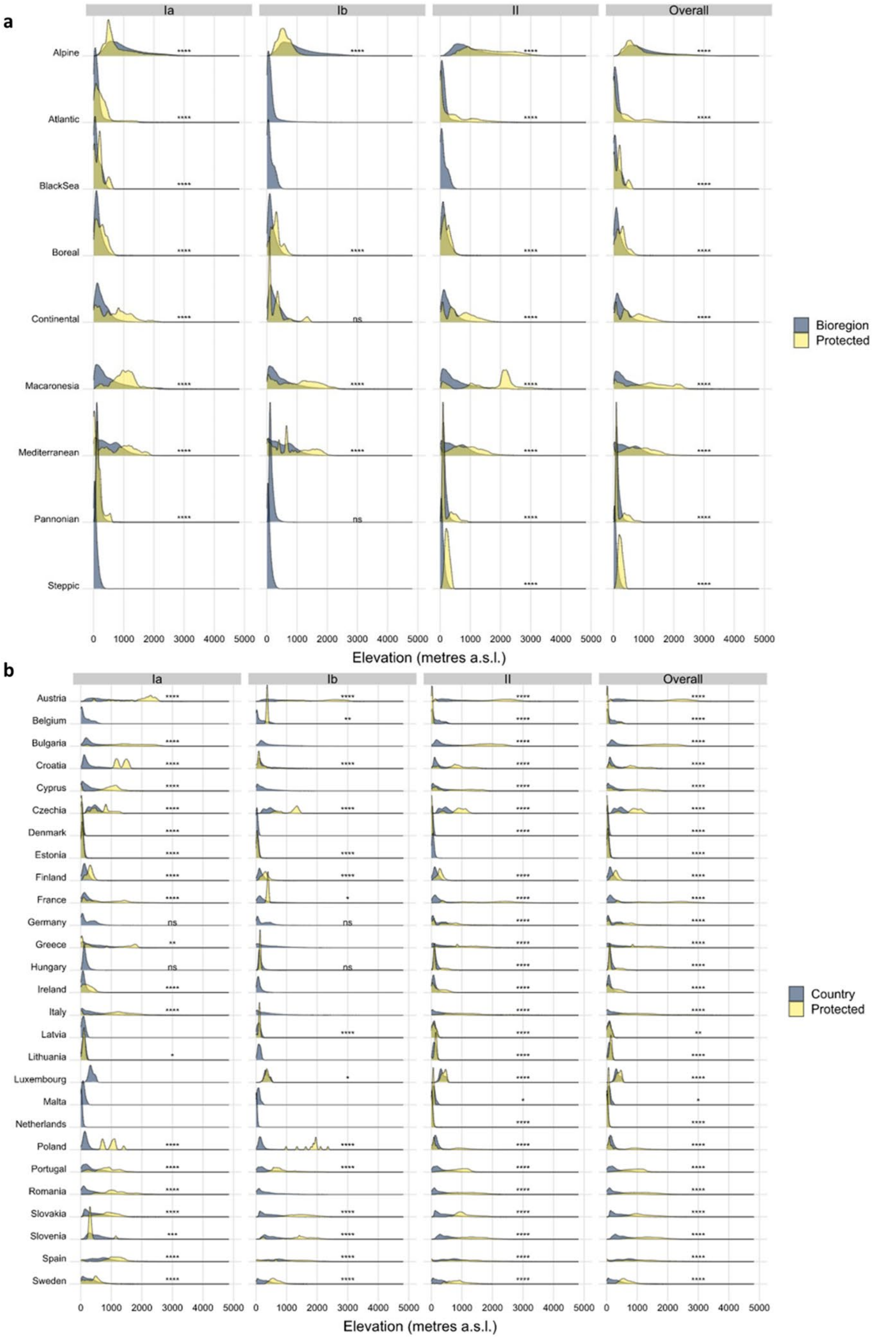

Fig. 5 **a** Comparison across biogeographical regions and **b** countries of the proportional distribution of strictly protected areas (IUCN category Ia, Ib, and II) across elevation range with respect to the proportional distribution of land area. Stars represent the level of statistical significance (Wilcox test with Holm correction with * 0.01 < p-value < 0.05, ** 0.001 < p-value < 0.01, *** 0.0001 < -p-value < 0.001, **** p-value < 0.0001 and ns for non-significant results)

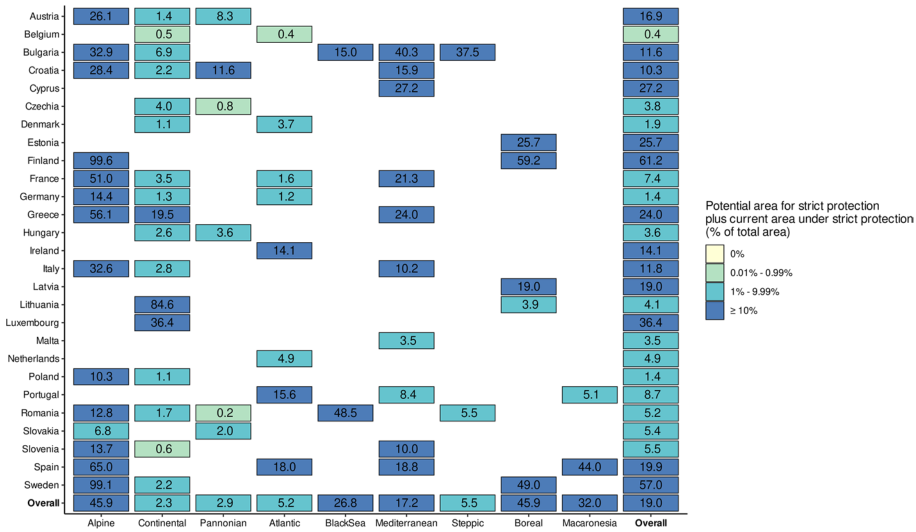

Fig. 6 Potential area (%) for strict protection plus current area under strict protection in each biogeographical region and EU27 country

and Malta in the Mediterranean region; in these cases, there is not enough potentially available area for expanding the *StPA* network. For the *Steppic*, *Atlantic*, *Pannonian* and *Continental* regions there is no potentially available area to expand the *StPA* network up to the 10% target (Fig. 6), but we identified sufficient available areas to pass the 10% target in some specific cases: Bulgaria in the *Steppic* region, Ireland and Portugal in the *Atlantic* region, Croatia in the *Pannonian* region, Luxembourg, Greece and Lithuania in the *Continental* region (Fig. 6).

Strict Protection within the EU Natura 2000 network in the EU27 ranges between 10 and 40% and shows high variability across countries, as well as the percentage of Natura 2000 areas under strict protection, which starts from the minimum of 0.6% in Belgium and reaches a maximum of 72.7% in Finland, with 14 out of 27 nations under 10% (Supplementary Table 4).

Discussion

Amount of strictly protected areas in EU27 countries

The number of *StPAs* in EU27 countries is quite high, but their cumulative area is low with respect to the land area and they are unevenly distributed across biogeographical regions, countries, and elevations. This represents a major risk in terms of responding to climate change and maintaining long-term conservation capacity (Hoffmann et al. 2019). In fact, only 3.37% of the continent is covered by *StPAs* (IUCN categories Ia, Ib, or II), and an additional area almost twice the present one (273,909.34 km^2) should be added to this network to reach the 10% area target set up by the EU27 BIO-2030 strategy.

While absolutely needed, the area enlargement of *StPAs* should be coordinated across the EU27 countries to achieve a representative coverage of biogeographical regions, countries, and elevational ranges. Our analysis emphasizes that existing StPAs are biased towards the places least likely to face land conversion pressures, such as higher elevations and specific regions/countries. The preferential location of protected areas in higher latitudes and elevations, as well as steeper slopes, is a typical bias (Joppa et al., 2009; Sayre et al. 2020; Vimal et al. 2021). Protecting these areas is important, but most of them are unlikely to face conversion to other land uses and can be considered safe even in the absence of formal establishment of protected areas. We argue that a strategic enlargement of StPAs should be aligned to preserve relevant biodiversity and ecosystem processes across the whole range of European geographical and ecological conditions.

Area coverage of strictly protected areas across biogeographical regions, countries and elevational belts

At the biogeographical scale, all biogeographical regions except the "*Alpine*" and "*Macaronesian*" ones have very limited protection, with the cumulative cover of the StPAs far below the 10% target. The "*Atlantic*", "*Black Sea*", "*Steppic*", "*Mediterranean*" and "*Continental*" biogeographical regions, which collectively represent most of the area of Europe and host highly diverse ecosystems and communities, rare species, and also megafauna (Underwood et al. 2009) need an increase of *StPAs*. For example, the Mediterranean region of Europe is a biodiversity hotspot but scarcely protected (Médail and Quézel 1999; Underwood et al. 2009; Klausmeyer & Shaw 2009), much less than the equivalent ecosystems in Australia or California (Baquero & Tellería, 2001). Moreover, we highlighted how the "*Steppic*" biogeographical region lacks *StPAs*, especially in the strictest (type Ia and Ib) protection category. The minimal amount of currently existing *StPAs* in most biogeographical regions and countries calls for urgent conservation action (Di Marco et al. 2019; Chauvenet et al. 2020) since these areas are essential for the long-term conservation of viable ecosystems.

Although several northern European countries have a relatively high level of land area under strict protection, most countries appear to have few *StPAs*. In addition, there are many differences in protected area classification across countries; for example, France has very few national parks (excluding overseas territories) but has many regional ones (Guignier & Prieur 2010; Hoffmann et al. 2018). This may affect our results, as it is difficult to match these regional parks to IUCN categories. Similar cases exist in other countries, representing a conservation concern and not simply a legislative issue. The level of protection in regional parks, as well in the majority of the Natura 2000 sites is importantly lower than in *StPAs,* with several management activities, such as hunting, agriculture, forestry, and even building often allowed. Consequently, protected areas and Natura 2000 cannot provide a level of protection comparable to that achieved by StPAs, which are dedicated to the preservation of natural processes (Aitchison, 1984; Tsiafouli et al. 2013) and therefore cannot be included in the calculation of the 10% target. In addition to the biases across biogeographical regions and countries, our analyses showed that the distribution of *StPAs* was largely biased towards higher altitudes. This means that the StPAs within a given biogeographical region or country do not protect a representative portion of their actual area, and leave a significant part of habitats and ecosystems unprotected against land conversion and habitat degradation (Joppa & Pfaff 2009; Pimm et al. 2018; Hoffmann et al. 2019; Sayre et al. 2020).

Scenarios for area expansion of strictly protected areas in Europe

There is an urgent need to establish new *StPAs* by using an approach targeted at protecting a proportion of land that is fully representative of the range of geographic and ecological conditions. This can be achieved by analyzing spatial gradients of biodiversity, presence of local hotspots, and site complementarity in species composition and ecosystem functions, possibly using a diversity of taxa. This planning needs to be paired with biodiversity hotspots and gradients of species richness and endemism, which still need to be fully assessed (see e.g., Večeřa et al. 2021, for the richness of vascular plant families) or for changes depending on human transformation (see Hatfield et al. 2022, for changes in species richness of mammals). However, the first basic condition to implement the 10% of the area as strictly protected is the actual availability of such area. Our analyses demonstrated that in the *Alpine*, *Boreal*, *Macaroniesian*, *Black Sea,* and *Mediterranean* regions, might be possible to find potentially available areas to reach the 10% *StPA* target for most EU27 countries, while in the *Steppic*, *Atlantic*, *Pannonian,* and *Continental* regions there is little potentially available area and does not permit to reach the 10% target in most countries.

The evidence presented shows the low area coverage of existing *StPAs,* and how far it is from the 10% target set by the EU BIO-2030. Concerns about the capacity of the currently protected areas to preserve biodiversity at the continental scale in Europe have already been raised (Pimm et al. 2018; Hoffmann et al. 2019; Sayre et al. 2020). Even the achievement of the basic target of area expansion of StPAs to 10% of the EU countries is not an easy task and would require a coordinated strategy, taking into account shared criteria for developing a continental conservation plan to increase *StPAs* and achieve the EU BIO-2030 targets (Jenkins & Joppa 2009; Pimm et al. 2018; Hoffmann et al. 2019; Vimal et al. 2021; Hoffman 2021).

The achievement of the 10% target can be based on a more strict conservation approach to areas that are already under a lower level of protection. This is the case of Natura 2000 areas, which from our analysis shows a quite good country cover (ranging from 10 to 40%) but very low strict protection in most of the countries, and many national parks, which in theory belong to IUCN category II (or I), but often allow a wide variety of land-use activities (particularly in the non-core zones), such as forestry, or domestic animal grazing. Such activities, while often preserving cultural landscapes, typically hinder the preservation of fundamental ecosystem processes and prevent the establishment of large carnivores (Bargmann et al. 2019). Establishing the 10% target of StPAs is in line with the preservation of broad spaces without (or very limited) anthropogenic disturbance to ensure ecological connectivity (Perino et al. 2019; Brackhane et al. 2019; Bargmann et al. 2019; Saura et al. 2019; Ward et al. 2020).

At the same time, we believe that other socio-political factors will affect the upgrading and reation of new StPAs, and these must be specifically addressed in future analyses aimed at specifically identifying suitable territories for the expansions of strict conservation expansion.

Anthropocene refugia and policy-oriented rewilding

The 10% area target of StPAs is fundamental to achieving long-term conservation of large-scale ecosystem processes and biodiversity, also at the perspective of a massive rewilding of many presently transformed areas (Carver et al. 2021). We also argue that preserving a significant amount of area under a strict conservation regime can provide insurance for the long-term preservation of the basic ecological mechanisms since it is now evident that chaos is not rare in natural dynamics and there are intrinsic limits of steady-state approaches to conservation and management (Rogers et al. 2022). In this perspective, we additionally propose that at least half of the strictly protected area of each biogeographical region and country should be protected under the strictest regime (IUCN Ia and Ib). This will allow a significant proportion of EU area to act as Anthropocene refugia, namely areas that provide spatial and long-term protection from human activities and that will remain suitable for sustaining biodiversity and ecological processes in the long term (Monsarrat et al. 2019). A first step in this direction would be to increase the share of the strictest protection categories (Ia and Ib) within existing protected areas, such as national parks. Additional areas need to be placed under strict protection, possibly those characterized by a high level of naturalness and large enough to ensure the conservation of major ecosystem processes or even rewilding (Carver et al. 2021). A growing body of literature indicates that rather than managing or restoring certain habitat conditions, new conservation opportunities are offered by rewilding, a process-oriented approach (Higgs et al. 2018; Perino et al. 2019). The recently introduced concept of "non-use rights" (Leonard et al. 2021) applied to such protected areas would facilitate the merging of biodiversity conservation with human activities. Finally, we propose that such a pioneering approach of 10% extension promoted by the EU27 and our feasibility analysis could be adopted by other countries in the world to expand their networks of StPAs.

Conclusions

The current area of StPAs in the EU27 is extremely unbalanced across biogeographical regions, countries, and elevational belts and, with very few exceptions, does not comply with the 10% target of strict protection. Therefore, a significant amount of work needs to be done to achieve the conservation goals set by the EU 2030 Biodiversity Strategy, through rigorous international cooperative action among countries (Hoffman 2021) and to be fully representative of the range of geographic and ecological conditions. We suggest that in the Alpine, Boreal, Macaroniesian, Black Sea, and Mediterranean regions, it might be possible to find the available area to reach the 10% StPAs target at the scale of biogeographical regions and for most EU27 countries, while in the Steppic, Atlantic, Pannonian, and Continental regions, not enough land may be available to reach this target. The 10% area target under strict protection should be integrated with the 30% target of protected areas, dedicated to the broader protection of semi-natural habitats and cultural landscapes which also contribute to the conservation of biodiversity.

We stress that the actual scenario is likely worse than the one here depicted since the management of some protected areas is not always equivalent to the given IUCN category (Munoz and Hausner 2013; Hoffmann 2021). Some national parks, which in theory belong to IUCN category II (or I), allow a wide range of anthropogenic land-use activities (e.g. forestry, hunting, or domestic animal grazing), hindering the conservation of some ecosystem processes and the establishment of wild carnivores (Bargmann et al. 2019). There is a need to preserve broad spaces without (or with very limited) anthropogenic disturbance to ensure ecological connectivity (UNEP-WCMC and IUCN 2021b; Protected Planet 2020; JRC 2021; Brackhane et al. 2019; Bargmann et al. 2019; Saura et al. 2019; Ward et al. 2020).

Finally, the need for the enlargement of StPAs in EU27 countries should be accompanied by data harmonization through the Global Database on Protected Area Management Effectiveness (Coad et al. 2015) in conjunction with the management effectiveness tracking tool (Protected Planet 2020) or the Digital Observatory of Protected Areas (DOPA 2021). We also advocate initiatives such as Conservation Evidence (Conservation Evidence 2021), a free, authoritative information resource, supported by several conservation entities, designed to support decisions about how to maintain and restore global biodiversity summarising evidence from scientific studies.

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Declarations

Competing interest The authors declare no competing interests.

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