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Dimension and impact of biases in funding for species and habitat conservation

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ABSTRACT

Taxonomic and aesthetic biases permeate biodiversity conservation. We used the LIFE program—the European Union's funding scheme for the environment—to explore the economic dimension of biases in species- and habitat-level conservation. Between 1992 and 2020, animal species received three times more funding than plants. Within plants, species at northern latitudes, with broader ranges, and with blue/purple flowers received more funds regardless of their extinction risk. Conversely, species online popularity was only weakly positively associated with conservation expenditure. At the habitat-level, we found no relationship between expenditure and conservation status of the habitat. Our results can inform ways forward to achieve conservation goals that are comprehensive, sustainable, and cost-effective.

1. Introduction

Amidst a global climate emergency (Ripple et al., 2021; IPCC, 2021) and a biodiversity crisis unmatched in human history (Dirzo et al., 2014; Humphreys et al., 2019), the long-term survival of humanity will depend upon safeguarding biodiversity in all its forms and functions (Pollock et al., 2020; Díaz et al., 2019). Protecting biodiversity is our insurance to sustain the wealth of nature's services (Loreau et al., 2021), i.e. the provisioning of natural goods and life fulfilling conditions to humans, including cultural and spiritual well-being (Daily et al., 2000). One effective way to preserve the breadth of these services is to protect biodiversity in all its complexity, e.g. by maximizing conservation efforts across different branches of the Tree of Life (Harrison et al., 2014).

Yet, multiple biases permeate biodiversity conservation. For instance, mycologists have repeatedly emphasized that fungi are systematically ignored in global biodiversity goals (Gonçalves et al., 2021; Oyanedel et al., 2022), as are organisms living in out-of-sight ecosystems such as soils, caves, and deep-seas (Costello et al., 2012; Sánchez-Fernández et al., 2021; Guerra et al., 2021). Furthermore, aesthetics and charisma can cause researchers or decision makers to favour the study or protection of certain species and habitats (Stokes, 2007; Davies et al., 2018; Mammola et al., 2020; Adamo et al., 2021), even within groups that are generally considered as charismatic (Santos et al., 2020). These biases are also reflected in broader society and permeate into sustainable lifestyle decisions, citizen science engagement, and several other habits, with potential consequences for biodiversity conservation (Jarić et al., 2019). At this level, there is a strong bias in favour of taxa phylogenetically closer to humans and with anthropomorphic features (Miralles et al., 2019), explaining plant blindness (Wandersee and Schussler, 1999) and their online popularity mostly based on their utility for humans (Vardi et al., 2021). Such examples illustrate that despite recent heartening conservation successes (Pringle, 2017; Bolam et al., 2021; Knowlton, 2021), we are still far from establishing conservation goals that are at the same time comprehensive, ecologically sustainable, and

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cost-effective.

The corollary to the arguments above is that biodiversity conservation is primarily an economic problem (McCarthy et al., 2012). Funds are key for successful nature conservation, as shown by positive correlations between recovery progress and investment (Male and Bean, 2005; Miller et al., 2002). Parallel to political awareness about sustainability, investment in conservation is increasing in recent years. For example, the European Union (EU) recently launched a regional-level conservation strategy through its 2030 Biodiversity Strategy, proposing a financial investment of 20 billion euros annually (The EU 2030 Biodiversity Strategy, 2020). With such amounts of money at stake, an unbiased distribution of funds becomes exceedingly important. However, few studies have addressed taxonomic biases in conservation from a financial standpoint (Gordon et al., 2020; Negrón-Ortiz, 2014; Martín-López et al., 2009; Laycock et al., 2011), both at continental scale (Negrón-Ortiz, 2014) and at single country level (Martín-López et al., 2009; Laycock et al., 2011).

We aimed at understanding the impact of biases in conservation, by shedding light on the ecological, human, and socio-economic factors that may explain the observed patterns of investment in conservation. As a test case, we used the LIFE conservation program—the EU's main funding scheme for the environment. Recent studies on animals proved substantial taxonomic biases in LIFE funding in favour of birds and mammals (Sánchez-Fernández et al., 2018; Mammides and Kirkos, 2020; Mammola et al., 2020). Here, we extended these analyses beyond the animal kingdom and the species level, by including plant taxa and the habitat level. Plants exemplify well all the biases and problems discussed so far, by providing disproportionately more nature services (Quijas et al., 2010), while receiving disproportionately less conservation attention than animals (Wandersee and Schussler, 1999; Balding and Williams, 2016). Plant scientists have coined the term *plant blindness* (Balding and Williams, 2016; Negrón-Ortiz, 2014) or *plant awareness disparity* (Parsley, 2020) for the perceptual bias arising from higher preference for animals compared to plants, resulting in lower research interest and funds available for plant conservation. Furthermore, plant and habitat conservation are closely related, to the point that the conservation of a specific habitat can overlap with the conservation of certain key plant species therein, and vice versa (Heywood and Iriondo, 2003). The conservation of the entire habitat is the paradigm of biodiversity conservation in the EU; from this point of view, funding for certain key plants is at the same time an investment into habitats of high conservation value.

2. Material and methods

2.1. Data mining

We extracted information on the amount of funding allocated to terrestrial and aquatic species and habitats using the LIFE projects database (https://ec.europa.eu; accessed between January and March 2021). We created three interdependent datasets.

The first dataset ('LIFE dataset') is the cornerstone of the analysis and contains information on the amount of funding allocated by various LIFE projects to habitats and plant species. We first filtered LIFE projects specifically aimed at plants conservation, using the query STRAND = 'All'; YEAR = 'All'; COUNTRY = 'All'; THEMES = 'All'; SUB-THEMES = 'Plants'. We further refined the query focusing on THEMES = 'Biodiversity issues', 'Species', 'Biodiversity issues', 'Habitats', 'Climate change Adaptation', 'Information - Governance', matching 213 LIFE projects. For these LIFE projects, we manually extracted funding data and we double-checked species and habitats involved in the projects. LIFE projects without any assessed plant species and habitat or funding information were excluded, resulting in a final list of 179 LIFE projects. To define the amount of funds allocated to each species for each LIFE project, the budget of each project with multiple species was divided equally among the target species. We considered budgets as comparable among years and among countries. Most budgets were expressed in Euro (€). Those expressed in other national currencies (British Pounds or others before the Euro was established in 2000) were converted to Euro. Inflation was considered negligible between 2000 and 2021 in the EU (a little under 2 %; EUROSTAT data). The cost of living varies across countries within the EU, but a correction-coefficient could be applied only to the salaries of people therein, and LIFE projects usually involve more than one country, making the correction ineffective. Furthermore, the budgeting of LIFE projects takes into account the financial context of the countries in which the project will be developed (i.e. countries with a higher cost of living will require larger budgets). We therefore used the total amount of the project as a proxy of conservation effort.

The second database ('Species dataset') focuses on traits of vascular plants included in the list of LIFE projects. After excluding sub-species, we identified 228 species covered by the projects listed in the LIFE database. For each species, we extracted traits and information, which we hypothesise could be relevant to explain the allocation of conservation budget by species. We reported taxonomy using the accepted Latin names reported in The Plant List (Kalwij, 2012) and extracted the IUCN extinction risk category for each species (IUCN, 2020). We approximated species ecology using altitudinal distribution data, range size, and average latitude of the range. Furthermore, we included morphological traits that are potentially associated with aesthetic bias (Adamo et al., 2021), namely Raunkiaer's life forms (Raunkiaer, 1934), stem size, flower colour, and flowering duration. The database also included information about the presence/absence of each species in the 24 EU member countries, the conservation budget spent for each species, and the number of LIFE projects that included each species. We included LIFE projects involving the United Kingdom as a former EU member state; conversely, we excluded Croatia, Luxembourg, and Malta, since they were not partners in any LIFE projects on biodiversity conservation between 1993 and 2019. We extracted plant traits and altitude data from IUCN Red List (IUCN, 2020), Tela Botanica (Heaton et al., 2010), Actaplantarum (www.actaplantarum.org), Flora On (www.flora-on.pt), Flora Helvetica (Lauber et al., 2007), Flora Europaea (Tutin et al., 1976), and Flora Iberica (Aedo and Herrero, 2005) (all databases accessed in April 2021). Finally, we approximated species range size using species-occurrences available in Global Biodiversity Information Facility (GBIF; www.gbif.org; accessed in April 2021). We calculated three measurements: i) the area of the minimum convex polygon encompassing all localities (range area); ii) the dispersion of points around the distribution centroid (range dispersion) and iii) the latitude of the distribution centroid.

For each plant included in the database, we also characterised online popularity using a culturomics approach based on the volume of Internet searches performed on Google's search engine (Correia et al., 2021). We extracted data on the average monthly relative search volume recorded between January 2010 and December 2021 for each species from Google Trends. Relative search volume data obtained from Google Trends ranges from 0 to 100; the maximum value represents the highest proportion of total searches observed during any given month of the sampled period and all other values are scaled in relation to it. To ensure comparable data between species, we followed the same approach used by Davies et al. (2018) and Mammola et al. (2020). Specifically, we identified and validated species-specific topics (Correia, 2019) using R package 'gkgraphR' which we then used to run topic searches for combinations of multiple species. Each search after the first always included one species common to previous searches, and we used the values returned for this species in either search to estimate a scaling factor between searches. We calculated the scaling factor as the coefficient of a linear regression between the monthly values of either search. We selected the species used to calculate the scaling factor iteratively to ensure the scaling factor was calculated as accurately as possible based on i) the highest number of non-zero values between searches and ii) a regression R^2 value above 0.95. We then rescaled the monthly values of search interest for each species using this coefficient so that search volume estimates were comparable between species and averaged across 12 years of data (i.e. 142 months of search volume). The resulting metric provides an estimate of the average frequency with which each species was searched for every month over the last 12 years relative to the other species in our data and serves as a proxy for public interest towards each species over the sampled time period (Correia et al., 2021).

The third dataset ('Habitat dataset'), contains the characteristics of each habitat cited in the LIFE dataset. We considered several habitat features concerning their geography, conservation status, and species composition. Each habitat, classified using the EUNIS habitat classification (Moss, 2014), was associated with the following habitat features (Supplementary Table 2): hierarchy in the EUNIS classification, number of Sites of Community Importance (S.C.I.) including the habitat, number of EU member countries hosting the habitat, dominant bioregion of the habitat (European Topic Centre on Biological Diversity (ETC/BD), 2016), the worst conservation status reported for the habitat (between bad, inadequate, favourable), the percentages of S.C.I. classified as bad, inadequate, favourable, or unknown status of conservation, number of priority species per habitat (species list is available in the Habitats Directive 42/93/EEC), global area covered by the habitat in EU, average elevation of the habitat in EU, the presence/absence of peculiar species (orchids and/or insectivorous plants), budget spent in conservation in LIFE projects, number of LIFE projects including the habitat. We considered orchids and insectivorous plants as "peculiar species" based on multiple factors: popular preference for these plants (e.g., orchids and insectivorous plants are among the most traded plants in both legal and illegal markets; Hinsley et al., 2017; Fukushima et al., 2020; Cross et al., 2020), gardening trends, and presence of habitat types in the Habitats Directive specifically dedicated to these plants (e.g., habitats labelled as *important orchid sites* such as Habitat type 6210) or characterised by the presence of these species (e.g., fens, bogs, mires, and other wetlands) (Keddy, 2010). We extracted habitat features from the European Nature Information System (https://eunis.eea.europa.eu/) or from the Natura 2000 shapefile, which we analysed in QGIS v3.10 (Qgis, 2016).

2.2. Data analysis

We ran all analyses in R (R Core Team, 2019). We first tested for differences in conservation investment and number of LIFE in plant versus animal species with a Wilcoxon signed-rank test. We obtained data about the conservation investment devoted to animal species from the database provided in (Mammola et al., 2020).

Subsequently, to obtain a deeper understanding of the factors underlying the observed pattern of conservation investment among plant species and habitats, we constructed two sets of regression models (Zuur and Ieno, 2006). Using the Species dataset, we explored relationships between the cumulative budget each plant species has received throughout the LIFE program and different plant traits. Using the Habitat dataset, we explored relationships between the cumulative budget each habitat had received and the measured habitat features. Note that, for both datasets, cumulative budget and number of LIFE projects were significantly and positively correlated (Pearson's $|r| > 0.7$); thus, we only used cumulative budget as a response variable.

We conducted data exploration following (Zuur et al., 2010). Using dot charts, we visually checked homogeneity of all continuous variables and the presence of outliers. After visual inspection, we log-transformed non-homogeneous variables, when appropriate (Tables S1–2). We verified collinearity among continuous predictors with pairwise Pearson's r correlations. We visualised potential associations between continuous and categorical variables with boxplots.

In the species dataset, Raunkiaer's life forms were associated with plants size, and there was a significant correlation ($|r| > 0.7$) between minimum elevation, maximum elevation, and range area. We thus excluded the Raunkiaer's life forms, minimum elevation and range area from the species dataset analysis. In the habitat dataset, bioregions were associated with the number of S.C.I., elevation, and area; conservation level was associated with %bad, %inadequate and %favourable; number of priority species was associated with number of species in the habitat dataset. Collinearity analysis in the habitat dataset revealed significant correlations between the number of S.C.I. with both area and number of countries. Bioregions, %bad, %inadequate, %favourable, number of priority species, area and number of countries were thus excluded from the habitat dataset analysis.

We constructed Generalized Linear Mixed Models (GLMM) with the R package glmmTMB (Brooks et al., 2017), specifying a negative binomial distribution and a log link function. The negative binomial distribution is often used for count data (note that the budget was rounded to remove decimals) and the log link function ensures positive fitted values. We could not use a Poisson distribution due to overdispersion. We included the family taxonomic rank of each plant species as a random factor, to account for the fact that species within the same family may often share more similar traits than expected from random. Following a similar reasoning, we used the bioregion as a random factor in habitat's regression models.

We built GLMMs (Eq. (1): Species model; Eq. (2): Habitat model) using all the non-collinear variables and the non-associated factors (Tables S1, S2) selected after data exploration (the equations are in R notation):

$$\text{Budget} \sim \text{sc\_Size} + \text{sc\_Hmax} + \text{sc\_mLatitude} + \text{sc\_Range} + \text{sc\_Popularity} + \text{IUCN} + \text{Color} + (1|\text{Family}) \tag{1}$$

$$\text{Budget} \sim \text{Conservation\_Low} + \text{Peculiar\_sp} + \text{sc\_nSCI} + \text{sc\_nSpecies} + \text{sc\_Elevation} + (1|\text{bioregion}) \tag{2}$$

Note that we scaled and centered all continuous explanatory variables to facilitate model convergence and ensure comparability among estimates. In discussing model results, we adopted an evidence-based language, emphasizng effect sizes and directions of effects rather than purely focusing on significance (Muff et al., 2022). Exact model estimates and p-values can be found in Table S3. We validated models with the R package performance (Lüdecke et al., 2020) by constructing standard validation plots using residuals and fitted values (Supplementary Fig. S1). Given that we were not fully satisfied by the quality of some validation plots (Supplementary Fig. S1), which is largely attributable to the relatively low sample size (namely the number of species and habitat listed in the Habitat Directive), we decided to double-check the coherence of the results by constructing Bayesian models, fitted with the R package brms (Bürkner, 2019) and the same model structure as in Eqs. (1) and (2). Bayesian models converged properly, and revealed the same directions of effects detected with the frequentist approach (Supplementary Fig. S2; Supplementary Table S4).

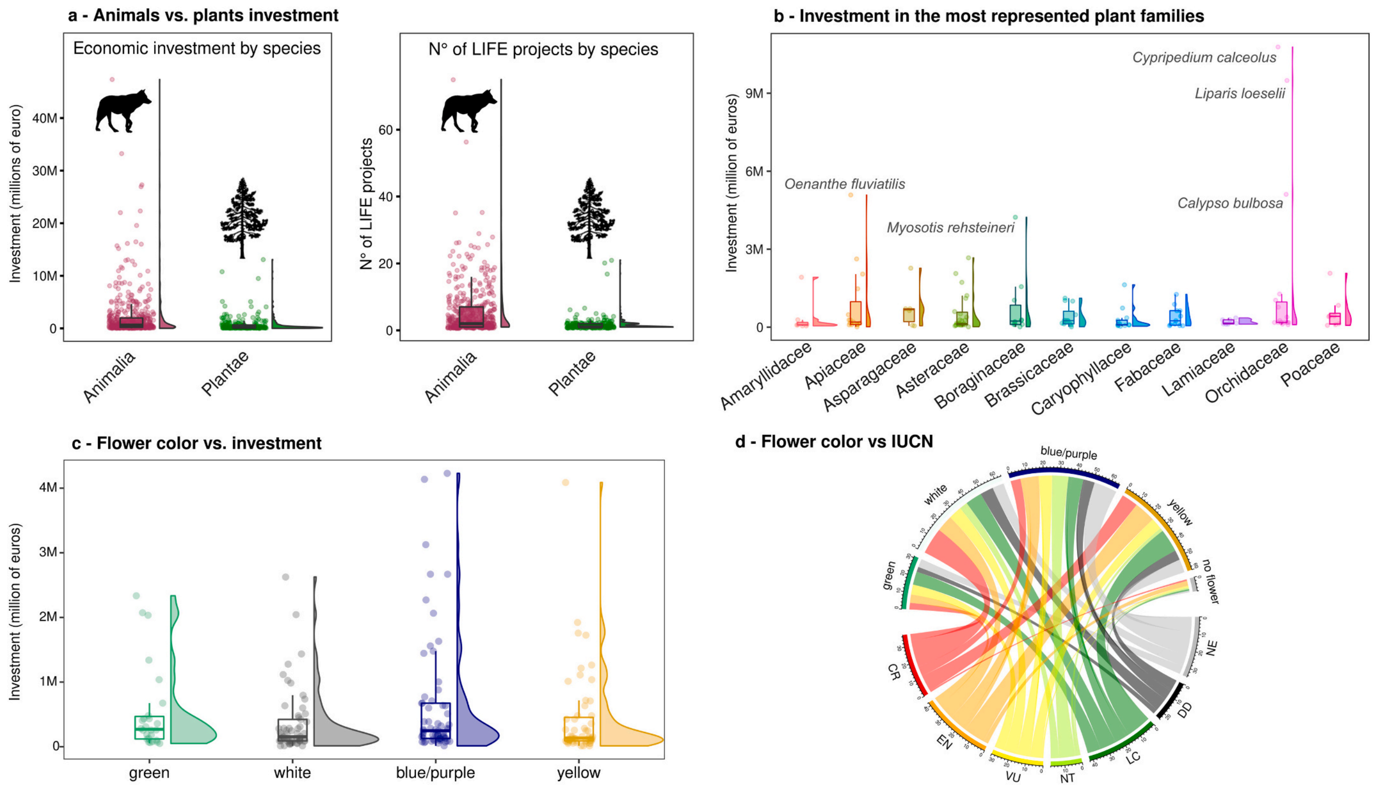

Fig. 1. Economic investment in animal and plant conservation. a) Breakdown of the budget allocation and number of projects between animals ($n = 471$) and plants ($n = 228$) covered by the LIFE projects funded between 1992 and 2020. b) Breakdown of the budget allocation by plant family. c) Breakdown of the budget allocation by flower colour. d) Chord diagram showing the relationships between flower colour and extinction risk [based on the International Union for Conservation of Nature (IUCN) red list] among the plant species included in the Habitats Directive (Council Directive 79/409/CEE). CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern, DD, Data Deficient; NE, Not Evaluated.

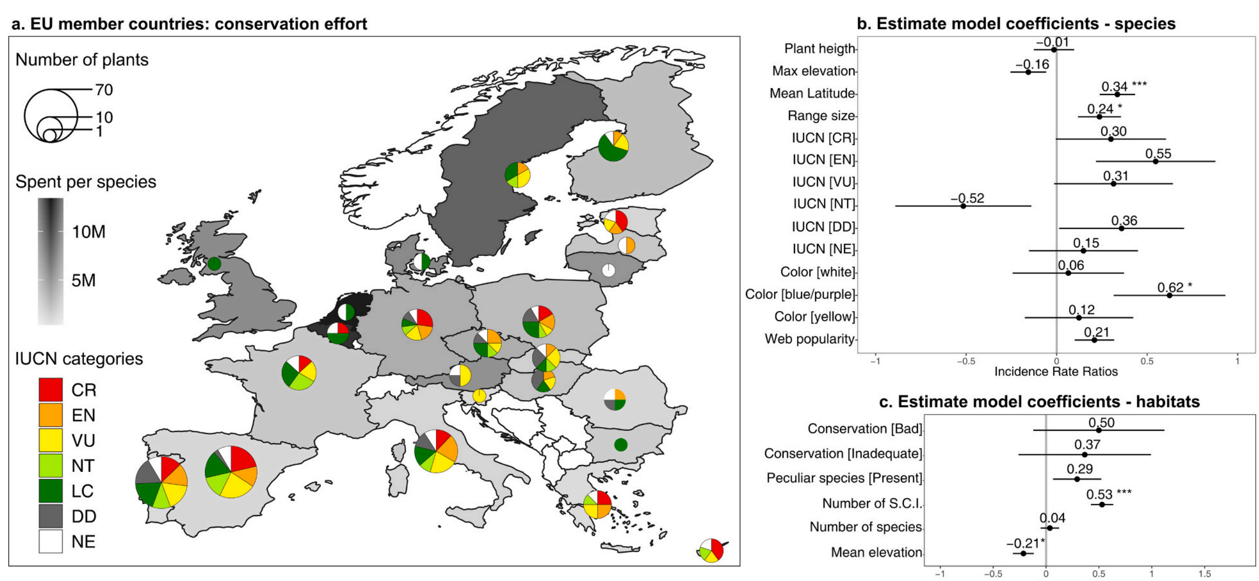

Fig. 2. Conservation efforts among European Union countries and main drivers in plant species- and habitat-level conservation. a) European Union's map showing total budget spent for plant species by country, the number of species in each country, and their breakdown in their International Union for Conservation of Nature (IUCN) red list categories. Countries with a white background are not EU members, except Croatia that has never been the lead partner country of a LIFE project. b–c) Incidence rate ratios and significance levels (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$) for all the explanatory variables included in the models for plants and habitats. Error bars indicate standard errors. P values for parametric terms were based on two-sided z-test. Full parameters for regression models are available in Tables S1 and S2. Exact p-values are reported in Table S3.

3. Results

3.1. Conservation bias among plant taxa

Over the three decades of the Habitat Directive (Council Directive 79/409/CEE), animal species received three times more funding (Wilcoxon Test: W = 75,367, $p = 8.728e^{-12}$) and LIFE projects (W = 70,779, $p < 2.2e^{-16}$) than plants (Fig. 1a). Regarding plants, in Europe, three of the five most funded species are orchids (Fig. 1b), being *Cypripedium calceolus* the species receiving most of the funds. When analysing the specific factors driving conservation funding, we found no relationship with extinction risks, however we found a positive relationship between funded budget and species' range size, latitude, and flower colour (Fig. 2b; exact estimates in Table S1). Conversely, we did not find any strong association between extinction risk and conservation funding (Fig. 1d). In particular, species with greater range size and occurring at northern latitudes received more funding. There was also an effect of flower colour (Fig. 1c), with species bearing blue/purple flowers receiving more funds. Species online popularity was only weakly positively associated with conservation expenditure (Fig. 2b, Table S1). The orchid *Cypripedium calceolus* received the most online attention.

3.2. Conservation effort by country and habitat

Conservation effort and expenditure by country is summarized in Fig. 2a. Sweden, Belgium and Spain were the first three countries in terms of budget spent for plants and habitats conservation, with >40 million € for the conservation of respectively 6, 4 and 70 plant species (or 37, 92, 202 different habitats). This confirms the general trend of a higher expenditure/investment per species in northern countries (with Netherlands at the first place, followed by Belgium and Sweden) compared to Mediterranean and Macaronesian countries. This effect was recovered when looking at the effect of latitude on species-level expenditure, measured as the centroid of the range of each species, that reveals a northward skewness of funds (Fig. 2(b)).

Funding was significantly driven by the number of Sites of Community Importance (S.C.I.s) held by a given habitat. Furthermore, elevation was inversely associated with funds, although this effect was weakly significant. A third, non-significant factor retained in the model was the presence of peculiar species in the habitat (orchids and/or insectivorous species) (Fig. 2c).

4. Discussion

We conducted an exploratory analysis on the expenditure in species and habitat conservation through the LIFE program by the EU. We demonstrated that several biases dissipate resources in species conservation and that funding biases are more evident for single-species than for habitats. Our results improve understanding of the magnitude of conservation biases across broad-scale conservation programs. They also represent a starting point to formulate recommendations aimed at improving cost-effectiveness of conservation. In the specific case of the EU, reducing subjectiveness in conservation expenditure, investing more towards habitats rather than species conservation, and more equitably partitioning conservation funds across state members based on their biodiversity, would all contribute to mitigate prevalent funding biases. This is even more urgent given the aims of the recently put in motion EU Biodiversity strategy for 2030 (The EU 2030 Biodiversity Strategy, 2020).

4.1. Conservation bias among plant taxa

Animal species received more funding than plants in Europe. Similar results from the USA (Balding and Williams, 2016; Negrón-Ortiz, 2014; Male and Bean, 2005) confirm the general biased disparity of attention to a few attractive and charismatic animal taxa that are phylogenetically closer to humans (Lišková and Frynta, 2013; Maiorano et al., 2015; Mammola et al., 2020; Gonçalves et al., 2021). Regarding plants, orchids, a family renowned for the beauty of its flowers, but also for the complexity of its conservation protocols (due to the complex biology that includes presence of mycorrhizal fungi and specific pollinators, and stable environmental conditions; Swarts and Dixon, 2009) received more funds than all the other plant families. The orchid receiving most funds was *Cypripedium calceolus* sparking great commercial, scientific and conservation interest (Gargiulo et al., 2021; Jakubska-Busse et al., 2021; Fay, 2018). Conversely, insectivorous plants, the other "peculiar species" which we considerred in the habitat model, are mostly missing in the Habitats Directive Annex II, thus they are not eligible to be directly targeted in LIFE projects. In fact, the species dataset hosts only *Aldrovanda vesiculosa* as an insectivore plant. This species is among the 20 most funded and popular species (see Fig. S3), highlighting a certain interest around this plant. *A. vesiculosa* is classified as Critically Endangered by the IUCN (Adamec, 2018) and is found in one of the most endangered habitats worldwide, the planitial swamps (Keddy, 2010). The large amount of funds allocated to this species are probably justified by its rarity and conservation challenges (Adamec, 1997), but it is difficult to have a clear picture of the insectivores as a group.

The pattern that species with larger ranges are receiving more funding is probably linked to a greater number of researchers, stakeholders or countries being likely to access funding, while endemic species will only attract the attention of regional or national institutions. Specifically, plants with more northern distributions were favoured at the expense of Mediterranean and Macaronesian species. This creates a mismatch between species biodiversity and expenditure (Hermoso et al., 2017): southern, biodiversity-rich regions received less funds to protect more species, while in northern regions with lower diversity, funds have been higher and divided by less species. While overall, biodiversity and conservation investments are positively associated, there are countries that received more (France, Finland, Germany and Great Britain) or less (Portugal, Slovakia, Hungary, Greece and Czeck Republic) investment than would be expected based on their biodiversity (Sánchez-Fernández et al., 2018).

Influence of colours in human life is multiple and studied in different contexts (Schloss and Palmer, 2011; Bellizzi and Hite, 1992). We found an effect of blue/purple flowers receiving higher funding (Fig. 1c), a result that matches previous evidence (Adamo et al., 2021). Among the blue/purple-flowered there are several species belonging to plant families such as Violaceae, Gentianaceae, and Boraginaceae, which are among the most beautiful and appreciated families (French flora-based data, personal communication). We did not find any association between extinction risk and conservation funding and this result suggests that funding decisions are not indifferent to human preferences. Whatever reasons may be behind these patterns, if glamorous species often enjoy special privileges in species conservation efforts, due to research, funding, and political and public support (Van Hook, 1997), this could prove problematic for the conservation of endangered, but less attractive, species.

While plant popularity was not strongly associated with conservation expenditure, the most popular species tend to be widespread whereas endemic species were generally less popular. Focusing on the twenty most popular plants (popularity score higher than the average; Fig. S3), eighth are used as either pharmaceutical plants (*Arnica montana*, *Origanum dictamnus*), Christmas decorations (*Ruscus aculeatus*), fine woods (*Quercus pubescens*), ornamentas (*Ulmus* sp., *Echium candicans*) or edible plants (*Gentiana lutea*). These results highlight the utilitarian popularity of plants (Vardi et al., 2021), similarly to what has been found for other biological groups such as birds (Ladle et al., 2019). For these species, the drivers of popularity may also increase their susceptibility to threats such as over-collection and illegal trade, resulting in further needs for conservation efforts and attention. On the other side, four of the twenty most popular plants are orchids, reiterating the influence of this plant family. Surprisingly three popular species were aquatic plants, including the insectivore plant *Aldrovanda vesiculosa* and the ecosystem engineer *Posidonia oceanica*, a seaweed endemic from Mediterranean Sea, strongly affected by climate change and by many anthropogenic factors (Houngnandan et al., 2020).

4.2. Conservation effort by habitat

Plant communities furnish nourishment and shelter for other organisms and shape their habitats (Evans, 2006). Ultimately, they are a constitutive part of the habitats. Therefore, plants and the habitats they dominate should be the strongholds for conservation policies in the EU. Thus, we constructed a second model to look at factors driving the distribution of funding into the conservation of specific habitats (Fig. 2 (c); exact estimates in Table S1). Since habitat-level conservation in the EU mainly occurs through the establishment of S.C.I.s, the positive relationship between funding and number of S.C.I.s per habitat is expected. A possible reason is that Alpine habitats are relatively undisturbed in Europe, and thus require limited conservation efforts to maintain local biodiversity compared to lower elevation habitats (Pullin et al., 2009). However, ongoing climate change is predicted to hit these environments heavily (Ciccarelli et al., 2008; Nogués-Bravo et al., 2007), and thus the situation may change in the future.

Several high-altitude habitats host orchids and insectivorous plants that we pooled in the category “peculiar species”. They also attract conservation investment due to their beauty, peculiar lifestyle, but also uniqueness of their habitats, often rich in water and rare species. Wetlands are among the most endangered environments in the world, moreover it is already clear that they are suffering from habitat loss, drought, and rising temperatures (Reid et al., 2019; Dudgeon et al., 2006).

Interestingly, we found no relationship between conservation funding and conservation status of the habitat—this variable was dropped during model selection—suggesting that habitat conservation efforts are possibly promoted regardless of their effective conservation status.

5. Conclusions

The limited investment in plant conservation is concerning, given that an estimated two in five plant species are at risk of extinction (Royal Botanic Gardens and Kew, 2020). With plant extinctions, we lose not only biodiversity, but also the base of food chains in nearly all ecosystems, and fundamental functions and services, such as food, materials, temperature mitigation, nutrient cycling, carbon storage, and many others. The EU investments in plant species conservation are partially influenced by popularity and aesthetics rather than extinction risk, and there is a strong latitudinal bias resulting in greater expenditure in areas with lower biodiversity. Habitat-level conservation appears to be less biased, although investment was not always focused on habitats with lower conservation status. Importantly, even if funds invested in habitat-level conservation are reasonably well aligned with current needs, the situation may drastically change under future climates (Lung et al., 2014; Dobrowski et al., 2021). Climate change mitigation must be at the centre of the conservation strategies of both single species and whole habitats. This goal will be tremendously hard to reach because Europe hosts one of the most fragmented and urbanized landscapes in the world (Verburg et al., 2010); harbouring at the same time unique and heterogeneous habitats (Medail and Quezel, 1997; Evans, 2006). Therefore, the EU Biodiversity Strategy for 2030 should be pursued with maximum care, by keeping the focus of conservation efforts primarily on the habitat-level, thereby avoiding prevalent aesthetic and taxonomic biases associated with single species conservation ((Balding and Williams, 2016; Negrón-Ortiz, 2014), (Balding and Williams, 2016; Negrón-Ortiz, 2014); Miralles et al., 2019; Parsley, 2020). In addition, endangered species may not be suitable for much of the sophisticated research that appeals to funders, and public support and consent is fundamental for public funding of conservation (see flagship species concept; Caro, 2010). Endangered species may indirectly benefit from studies on other popular species, but focusing on habitat level conservation, benefits should be more effective.

In a world of limited resources for conservation where research and funding biases may be unavoidable, perhaps the key issue is to be aware of these biases and to develop clear mechanisms to minimise them. The EU now has the power to rectify past omissions by increasing the objectivity of future conservation planning, turning “plant blindness” into “plant sightedness” and becoming “habitat visionary”.

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Data availability

Data and code to reproduce the analyses are available in Figshare (doi: 10.6084/m9.figshare.19168490).

CRediT authorship contribution statement

AM and SM conceived the study and ran analyses. MA, AL and RAC collected data. All authors discussed traits and analyses. MA, RS and SM wrote the first draft. AM, SW and MM provided most botanical arguments and interpretations thereof. All authors contributed to the writing with comments and suggestions, and approved the final version.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2022.109636.

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