Spatial prioritisation of EU's LIFE-Nature program to strengthen the conservation impact of Natura 2000

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Running title: Prioritisation of EU´s LIFE efforts.

Type of article: Policy Direction

Number of words in the abstract: 347

Number of words in the in the manuscript: 3148

Number of references: 21

Number of figures: 3

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Abstract

1. Despite advances in conservation efforts within Europe during recent decades, assessments highlight a need for adequate financing mechanisms to support the Natura 2000 network; the centrepiece of the EU´s Biodiversity Strategy. Besides the need for greater investment (currently only covering a fifth of the estimated cost of the network), better planning for this investment could help better achieve conservation goals.

2. We demonstrate a method that could be used to identify priority Natura 2000 sites, and species therein, that could guide investment in the future. We first used the lists of key species associated with each Natura 2000 site to map the distribution of all priority species covered by the Birds and Habitats Directives. We then used Marxan software to prioritise allocation of conservation funds among all Natura 2000 sites, while trying to mimic the observed conservation effort implemented under the LIFE Program, the main financial tool of the EU´s Biodiversity Strategy, in the period 1992-2013.

3. Some Natura 2000 sites show exceptional value, holding species that either do not, or only very rarely, occur elsewhere in the network. These priority sites were concentrated mainly on islands and in the south western, eastern and northern extremes of Europe´s mainland thus reflecting patterns in species richness and endemism.

4. We found a poor relationship between the priorities identified here and the way funds had been distributed in previous LIFE-Nature Programs.

5. *Policy implications*. We propose that prioritisation exercises like the one shown here could be used to inform a top-down EU regulation mechanism by providing lists of site and species priorities that better reflect European conservation needs. These recommendations, performed at continental scale, could then help guide LIFE project proposals from the Member States and fill the current gap in the coverage of priority species. This top-down control mechanism could be integrated in the current system of budget distribution, rather than replacing it completely, to enhance the efficiency of conservation investment in the EU and achievement of continental goals.

Keywords: Birds Directive, financial mechanisms, Marxan, Habitats Directive, prioritisation, top-down, EU, biodiversity strategy, Natura 2000, conservation

Introduction

The Natura 2000 network is the centrepiece of the EU´s Biodiversity Strategy, which aims to halt and reverse the loss of biodiversity in Europe by 2020 (EC, 2011a). To achieve this goal, the EU has declared over the last decades more than 27,000 Natura 2000 sites, which cover >1 million km^2 (18.3% of the land surface and about 6 % of marine area) in the EU, becoming the World's largest network of protected areas (EEA, 2012). This network includes sites designated for protecting species and/or habitats listed as priority in the Habitat and the Birds Directives. The implementation of the EU´s environmental policy has been recently reviewed by the European Commission as part of the regulatory fitness and performance programme (REFIT; EC 2014). The preliminary findings of this assessment indicate that although there have been substantial advances in the implementation of the Natura 2000 network, more progress is needed in areas such as the development of conservation measures and adequate financial mechanisms (EC, 2016). There is evidence of the positive impact of the Directives on the EU´s biodiversity (e.g., Sanderson et al. 2015; Kallimanis et al. 2015), although the overall improvement reported for species in favourable condition in the last assessment (EEA, 2015) has been very small (1-2% more species in favourable status than in 2007), while there is still a significant proportion of species whose condition continues deteriorating (European Court of Auditors, 2017).

As a continental initiative that pursues continental targets, the Natura 2000 network is based on the principle of solidarity between Member States. Although the main responsibility for financing this network resides in each State, the Habitats Directive explicitly recognises the need of financial support by the EU to ensure its adequate implementation. The cost associated with managing Natura 2000, including the management and monitoring actions or the development of management plans, was estimated in 2010 at about €5.8 billion annually (Kettunen et al., 2011). There are different mechanisms to contribute to funding Natura 2000, including the European Agricultural Fund for Rural Development (EAFRD), Structural and Cohesion Funds (ERDF), the European Fisheries Fund (EFF), 7th Framework Program for

Research and Development and the LIFE Program. Despite all these different sources being available, the investment made has been insufficient to cover the needs. Kettunen et al. (2011) estimated that the financial allocations for Natura 2000 from the EU budget were between €550 – €1150 million annually in the period 2007-2013, which only represents between 9-19% of the financing needs and a very small portion (>0.5%) of the EU´s budget. With the exception of the LIFE Program, funds are not earmarked for conservation and then not secured for actions directly related to the implementation of Natura 2000 and conservation of biodiversity (Kettunen et al, 2009). For this reason, LIFE has become the main financial tool for the implementation of conservation projects in Europe (Hermoso et al., 2017). Because of the poor integration of Natura 2000 in mainstream EU funding schemes there is a risk that the available funds continue to be insufficient to attain the conservation goals pursued by the EU (European Court of Auditors, 2017).

Despite the financial effort being made since 1992 under the LIFE program, Hermoso et al. (2017) reported that there were some aspects to be improved in terms of distribution of funds to address the poor coverage of threatened priority species, and regions where they occur, and then better cover continental conservation needs. About only half of the species listed in the Directives, mostly Least Concern species according to IUCN assessments, had received funds from the LIFE-Nature Program until 2013. Hermoso et al. (2017) argued that a better planning at the continental scale is needed to identify priority species and regions where to focus LIFE investment and fill the conservation gaps. This is especially important given the very limited financial resources available and the strong spatial differences in funding needs and capacity to cover them.

Here, we show how investment in Natura 2000 under the LIFE Program could be spatially prioritised to increase the coverage of priority species and then help fill the gap identified in Hermoso et al. (2017). We use Marxan (Ball et al., 2009), a commonly applied tool to inform decision-making in conservation, to identify priority sites in Natura 2000 for investment in conservation actions for all priority species listed in the Directives. We also compare the benefits of this approach against the observed pattern in investment in the period 1992-2013 in terms of spatial coverage of conservation needs in the EU and discuss how it could be incorporated into the existing mechanisms of distribution of funds.

Materials and Methods

Data on Natura 2000 and species distribution

We sourced the most up to date extent of Natura 2000 from the European Environmental Agency (http://www.eea.europa.eu/data-and-maps/data/natura-5). We then used this dataset to map the spatial distribution of species, by using the list of key priority species for which each Natura 2000 site was declared. Although these lists do not comprise a complete inventory of species per Natura 2000 site they represent local and continental conservation priorities, given that they reflect the reasons for which each Natura 2000 site was declared in accordance to the Habitats and Birds Directives. Moreover, LIFE funds focus on projects that target specifically these species (although other threatened species are also eligible) as they are all considered priority in the Directives, making these lists especially relevant for our purposes. The final dataset on species distribution contained 336,264 records of 1,348 species across 22,732 Natura 2000 sites (Fig. 1).

Spatial prioritisation of LIFE projects

We used the software Marxan (Ball et al., 2009) to prioritise the allocation of LIFE-Nature projects to cover all of the species listed in the annexes of the Habitats and Birds Directives. In order to simulate the observed patterns in already funded projects we limited the number of species per project to 4, which is the median of species funded per project in the period 1992-2013. Whenever a Natura 2000 site had more than 4 species listed, a random subset of these species was selected and made available for the prioritisation process. This simulation was run 1000 times to account for the effect of stochastic selection of species. The limitation in the number of species available constrained the total number of species considered in each simulation to a subset of the total (767.5±11.1 species; average ± SD), although all of the species were present in at least one simulation, which means that every species would be covered by at least one solution. This approach also helped to account for the large differences in the number of species listed across Natura 2000 sites (range 1-303, Fig., 1) and avoid under representing species-poor sites in the solutions.

For each of the 1000 simulations we ran Marxan 100 times (5 million iterations each) and retained the best solution found for each simulation for further analyses. The best solutions among all 100 runs was identified as the one with the lowest score for the objective function being minimised (see below). To replicate the number of projects per species in the period 1992-2013, we set a target of two for each species so every species would be represented in at least two projects. Given the lack of consistent data on costs of projects for different species (not all species had been previously funded by LIFE-Nature and no data on the investment made per species were available) we opted for using a constant cost for all planning units or Natura 2000 sites in our case (cost=1). Under this assumption our optimisation problem translated into identifying a minimum set of Natura 2000 sites on which each subset of species could benefit from at least two LIFE projects. In addition, we did not use the boundary penalty available in Marxan´s objective function, given we were not interested in spatially clumping solutions. Therefore, our optimisation problem was:

$$\min \sum_{i=1}^{m} x_i c_i \quad \text{Formula 1}$$

$$\text{Subject to} \sum_{i=1}^{m} x_i a_i > t_j \quad \forall j \quad \text{Formula 2}$$

where, x_i is a control variable that takes a value of 1 when the Natura 2000 site i is selected and 0 otherwise; c_i is the cost of each i; a_i is the benefit for each species j provided by each i (presence of species in a given Natura 2000 site in our case); and t_j is the target for each species.

Under these premises the objective function that we tried to minimise was as stated in Formula 3.

$$Objective\ function = \sum_{i=1}^{m} c_i\, x_i + \sum_{j=1}^{n} SPF_j\ H(s) \left(\frac{s}{t_j}\right)$$

Formula 3

Where there are n species under consideration; SPF_j is a Species Penalty Factor or weighting factor that applies for not achieving the desired representation target for each species j; H(s) is a Heaviside function that takes a value of 0 when $s/t_j \leq 0$ and 1 otherwise; s the shortfall in targets no achieved and is measured as t_j-representation achieved (Formula 2); the ratio s/t_j equals 1 when the species j is not represented within the solution and approaches 0 as the level of representation approaches the target amounts. We used a constant SPF=10 for all species to ensure they all achieved the desired representation target.

We repeated the prioritisation process on the 1000 subsets of species, which derived 1000 best solutions as mentioned above. We then summarised them by calculating the frequency of occurrence of each Natura 2000 site across all best solutions and the frequency with which each species was selected in each Natura 2000 site. In this way, we obtained an estimate of the relative importance of each Natura 2000 site across Europe regardless of the particular selection of species being tested and the relevance of each Natura 2000 site for funding conservation for each species. To rule out the potential effect of the threshold used to the number of species allowed per project, we repeated the analyses by using two alternative thresholds (three and five species) and checked for the spatial concordance in selection frequency among results.

Comparison between LIFE-Nature projects and prioritisation results

Information on each of the 1,488 LIFE-Nature projects that were funded in the period 1992-2013 was recorded from the public database available at http://ec.europa.eu/environment/life/ for further comparisons with the results obtained from the prioritisation analyses. We retained all projects that targeted at least one species (n=1,288 projects) and compiled available data on financial information, spatial allocation (Natura 2000 sites where it was implemented) and species that benefited from each project´s report.

Given that we use a constant cost per project, we could not make direct comparisons between investment made under LIFE and the suggested in our results. However, we compared the distribution of conservation efforts in LIFE-Nature and the prioritisation exercise by computing the total number of species that had been targeted by these projects, the number of Natura 2000 sites selected, the number of projects per species and the combination of number of species x number of projects, as an estimate of the total benefit derived from the projects already funded under the LIFE-Nature program and our approach.

Results

The optimisation algorithm in Marxan was able to fulfil the representation target for all species whenever possible (ie., species occurred in ≥2 Natura sites). We found that on average 3,084 Natura 2000 sites were needed to represent 767.5 species. On the other hand, a total of 5,061 Natura 2000 sites and 689 species benefitted from the 1,288 LIFE-Nature projects funded between 1992-2013 targeting at least one species. The total benefit in terms of number of projects/ species and projects x species would be two-three times higher under the prioritisation approach than the observed in LIFE (Table 1).

The spatial distribution of Natura 2000 sites selected by Marxan at least once (n= 13, 765 sites) was evenly distributed across Europe, although there were some regions with a higher prevalence of sites recursively selected across all simulations (selection frequency >750 in Fig. 2). These included most of Atlantic islands of Spain and Portugal, Cyprus, several Greek islands, Corsica and the Balearic Islands (Supplementary Figure 1). In mainland Europe, some regions in Portugal, Southern Spain, Croatia, Hungary, Slovenia, Czech Republic and Northern Sweden stood out with several Natura 2000 sites with a high selection frequency regardless the subset of species being tested across the 1000 simulations (Supplementary Figure 1). This selection frequency was independent of the richness in key species, the relative commonness of species of each Natura 2000 (Supplementary Figure 2) and the threshold to the number of species selected per project (Pearson´s R^2=0.95 and R^2=0.96 between the selection frequency of Natura 2000 when using three and four species and five and four species thresholds respectively).

There were different spatial patterns in the selection frequency for common species (Fig. 3). For example, *Lanius collurio*, despite being listed in 4,727 sites, was preferentially selected in Natura 2000 sites of central Germany. Even rare species that are listed in only a few Natura 2000 sites showed spatial differences in the selection frequency across the few sites were they occur (e.g., *Lynx pardinus* in southern Spain, which was preferentially selected in Natura 2000 sites towards the southern distribution of the species).

Discussion

The spatial prioritisation of conservation efforts seems an unavoidable option (Hochkirch et al., 2012) given the need for more effective investment in Natura 2000 reported in recent studies and EU´s reports. These assessments point towards the necessity to improve the impact of the Birds and Habitats Directives on species´ conservation status, which has been small to date, and get closer to the achievement of the EU´s Biodiversity Strategy goals. However, the financial resources available are very limited and only cover a small proportion of what is needed (Kettunen.et al., 2011). Here, we have illustrated with a practical example how LIFE funds could be spatially prioritised to cover all species listed as priority in the Directives. Our results highlight Natura 2000 sites, and the species within them, that should receive preferentially funds for their strategic value to the achievement of continental conservation goals.

Although all Natura 2000 sites have intrinsic value for conservation as they have all been declared for protecting priority species and habitats, not all of them contribute equally to the achievement of the continental conservation goals. There are some Natura 2000 sites of exceptional value at the EU scale as they hold species and/ or habitats that do not occur elsewhere in the network or they do it very rarely. This is the case for example of most of islands in the Atlantic and Mediterranean Sea. For this reason, they appeared with the highest prevalence in our prioritisation regardless the particular set of species being used across simulations. The pattern in selection frequency in Europe´s mainland was related to the regional pool of species and their relative distribution range. For example, Mediterranean regions have higher richness and degree of endemism than other regions in the EU (e.g., Baquero and Telleria, 2001; Kukala et al., 2016), which made them more irreplaceable in the prioritisation process. Moreover, although less species-rich, some regions in northern and eastern Europe were consistently selected to represent the unique set of species that do not occur anywhere else within the EU (e.g., the wolverine *Gulo gulo* or *Primula scandinavica*).

The approach that we introduce could be used to enhance the implementation of Natura 2000 through better planned distribution of conservation efforts and cover more effectively the conservation needs derived from the EU´s Biodiversity Strategy. As currently done, available funds are distributed proportionally across Member States based on national population and the extent of Natura 2000 (EC, 2013a) to secure geographical balance in investment. The selection of projects to be co-funded under that national allocation is done on the basis of national priorities or recommendations made by each country (EC, 2007). However, given the spatial heterogeneity in the distribution of priority species (e.g., Kukkala et al., 2016), this system is prone to imbalances in the coverage of conservation needs (e.g., Hermoso et al. 2017) or inefficiencies associated with redundancies in the investment (e.g., same species covered by multiple projects in different countries). These imbalances are further increased by the differences in financial capacity by Member States to complementing EU funding for biodiversity with national resources, which constrains even more the uptake of EU funds (Torkler et al 2008). The regions with the highest number of priority species listed in the Birds and Habitats Directives are also the ones with the lowest funding capacity estimated from their GDP (Pearson´s $R=-0.36$, $p<0.001$). So, the principle of cohesion that guides EU´s policy should translate into a larger EU contribution in the least rich countries that make the largest contribution to the achievement of the EU´s Biodiversity Strategy as they hold large numbers of priority species and habitats. Several voices claim for the urgency of higher investment to help solve this problem (Hodge et al. 2015; Kati et al. 2015). An increase in the overall investment devoted to biodiversity conservation is highly desirable to help fill the gap between budget needs and availability (European Court of Auditors, 2017). However, the problem of under-financing areas with a large conservation responsibility and less financial capacity could remain under the same national allocation system. So it seems that a new mechanism of budget allocation is needed if continental conservation goals are to be efficiently achieved.

We propose that a prioritisation exercise, like the one we show here, could be used as the basis for a top-down regulation mechanism from the EU, that informs on priority sites, and the list of priority species within them, that should be the focus of investment by the LIFE Program. These recommendations, made at continental scale, should then help to foster project proposals from the Member States focused on the identified priorities. This top-down control mechanism could be integrated in the current system, rather than replacing it. So, for example, the bottom-up process of project proposals from Member States could be guided *a priori* by the top-down control mechanism regulated by the EU. In this way, the EU could try to encourage Member States to propose projects (e.g., Natura 2000 sites and the species for which the site was spotted as priority) that cover the priorities identified in continental prioritisation exercises. These priorities could also be periodically revised, for example after each LIFE program, to account for the investment already done and the new conservation needs that might emerge. This focus of attention on priority projects should not prevent from also encouraging other proposals (e.g., not centred on priority projects). However, this top-down control does not solve the problem by itself as the investment in priority projects would still be limited by national allocations, for example. New financial mechanisms or rules are then needed to complement, and not necessarily substitute, existing ones. Although beyond the scope of this study, there might be different alternatives to facilitating a more balanced investment in priority projects such as i) by modifying the co-funding rules, so priority projects would receive a higher co-investment by the EU (currently fixed at a maximum of 75%), or ii) by allocating a fixed proportion of the available budget for priority projects similar to already existing allocations for different types of projects (EC, 2013a).

Finally, a more integrated funding model for biodiversity conservation within all the different sources available is needed to further embed the implementation of the EU's Biodiversity Strategy goals into other relevant policy sectors and close the financial gap that might be limiting our capacity to halt biodiversity loss in Europe. As argued above, the increase in funds is no warranty of appropriate coverage of conservation needs and should be complemented with adequate planning, for example through prioritisation exercises like we demonstrate here. Future funding opportunities for biodiversity conservation might arise from growing initiatives at continental scale, such as the development of a network of green infrastructure that aims to identify priority areas for enhancing the connectivity among Natura 2000 sites and maintaining ecosystem services (EC, 2013b). Systematic planning approaches as we demonstrate here would also help integrate biodiversity in these programs by explicitly accounting for the benefits that these new management areas important for ecosystem services could bring to the overall objective of halting biodiversity loss (e.g., by improving connectivity among protected areas).

Given that we used a constant cost, our results represent a minimum set of priority Natura 2000 that could host a LIFE project in order to maximise the coverage of species listed as priority in the Birds and Habitats Directives. We could not consider any spatial differences in cost of implementation of the proposed projects that could lead to changes in the distribution of priority Natura 2000 sites and then we did not aim to minimise the total cost of the projects. The financial information available for each LIFE project was constrained to total investment made, with no indication on the relative expenditure done per species. This constrained our capacity to estimate the cost of each project as considered for the prioritisation approach (i.e., maximum of 4 species per project). This cost could be estimated as the sum of investment needed to address the threats to each species included in the project. Further effort is then needed to complete a comprehensive dataset with the estimated investment required for implementing conservation actions for each species and then enhance the value of the results for decision-making. These, should ideally consider spatially explicit factors such as the identity and intensity of threats affecting the species or socio-economic drivers such as labour cost, that reflect more realistically the spatial variation of investment needed. The analyses could also be extended to consider all threatened species in the EU, to account for the conservation needs that the continent faces (Hermoso et al., 2017). However, further efforts are also needed to better map the distribution of these species across Europe, currently only available at coarse scale for a reduced group of taxa (e.g., IUCN distribution data developed during the Red List assessments). A more comprehensive database on threatened species distribution at finer resolution could help identify Natura 2000 sites where to tackle conservation for all these threatened species.

Acknowledgements

V.H. and M.C. were supported by two Ramón y Cajal contracts funded by the Spanish Government (RYC-2013-13979 and RYC-2010-06431 respectively). We also thank A. Morán-Ordóñez for her help with the Marxan analyses.

Authors' contributions

VH conceived the idea, VH, MC, DV and LB designed the study carried out by VH. All authors contributed to interpreting the results.

Data accessibility: Data available from the Dryad Digital Repository. DOI:10.5061/dryad.kt741 (Hermoso et al., 2018).

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Supporting information

Additional Supporting Information may be found in the online version of this article.

Supplementary Figure 1. Average selection frequency of Natura 2000 sites within each region across 1000 simulations in Marxan.

Supplementary Figure 2. Plots of key species richness vs selection frequency and average commonness.

Table 1. Comparison LIFE-Nature and optimised investment.

Parameter	LIFE-Nature (1992-2013)	Spatial prioritisation
Number of species benefited	689	767.5± 11.1*
Number of projects per species	5.7 ± 17.8	12.9± 22.6
Number of Natura 2000 sites	5,061	3,084.1± 0.8
Number species x projects	3,970	9,798.5 ± 42.7

* This corresponds to the average number of species considered per simulation. The total number of species that were considered across all 1000 simulations was 1,348.

Figure 1. Number of priority species cited per Natura 2000 site, each represented by its centroid for mapping purposes.

Figure 2. Selection frequency of Natura 2000 sites (represented by its centroid for mapping purposes) across 1000 simulations. A different subset of species per Natura 2000 site was made available per simulation (maximum 4 species per Natura 2000 site) in the optimisation process to reproduce how LIFE-Nature projects had been funded in the period 1992-2013. A minimum number of two projects per species considered in each simulation was achieved to also replicate the number of projects funded by LIFE-Nature in that period.

Figure 3. Selection frequency of different species across all Natura 2000 sites (represented by its centroid for mapping purposes) after 1000 simulations.

Figure 1

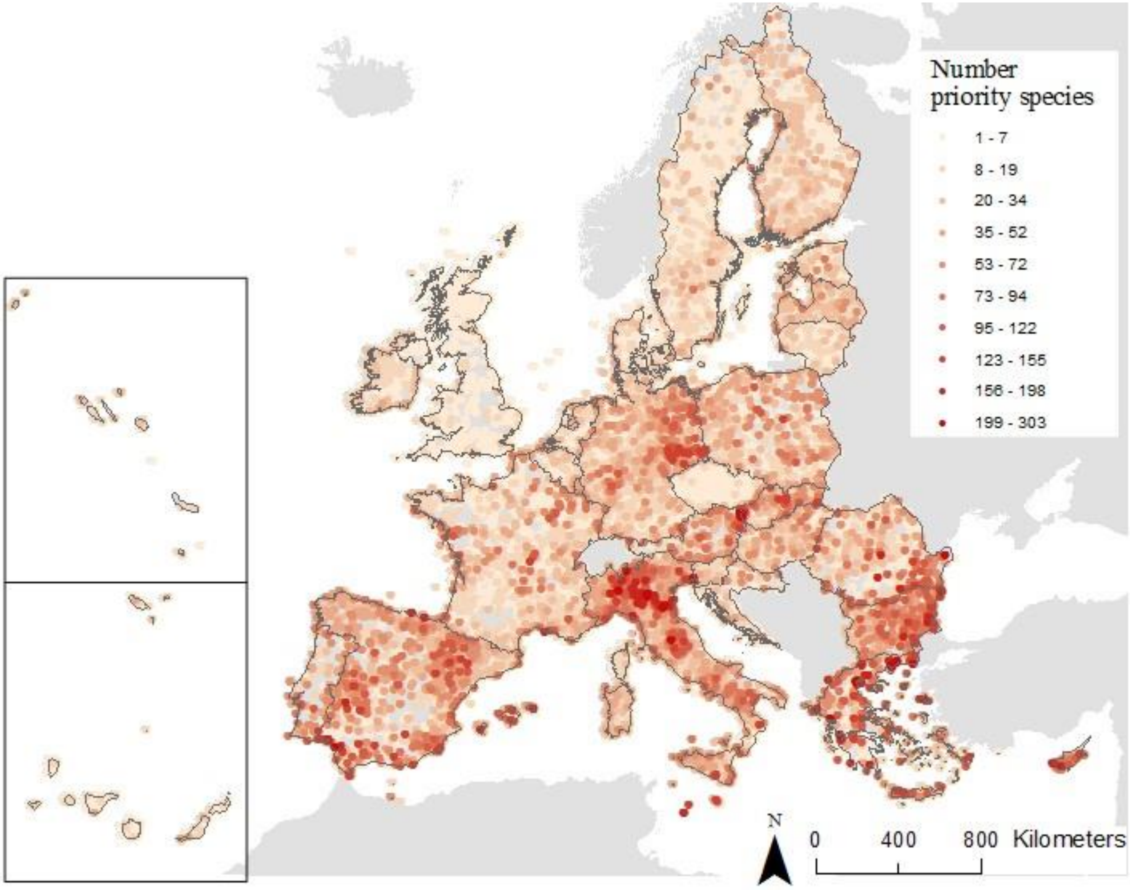

Number
priority species
1 - 7
8 - 19
20 - 34
35 - 52
53 - 72
73 - 94
95 - 122
123 - 155
156 - 198
199 - 303
N
0
400
800
Kilometers

Figure 2

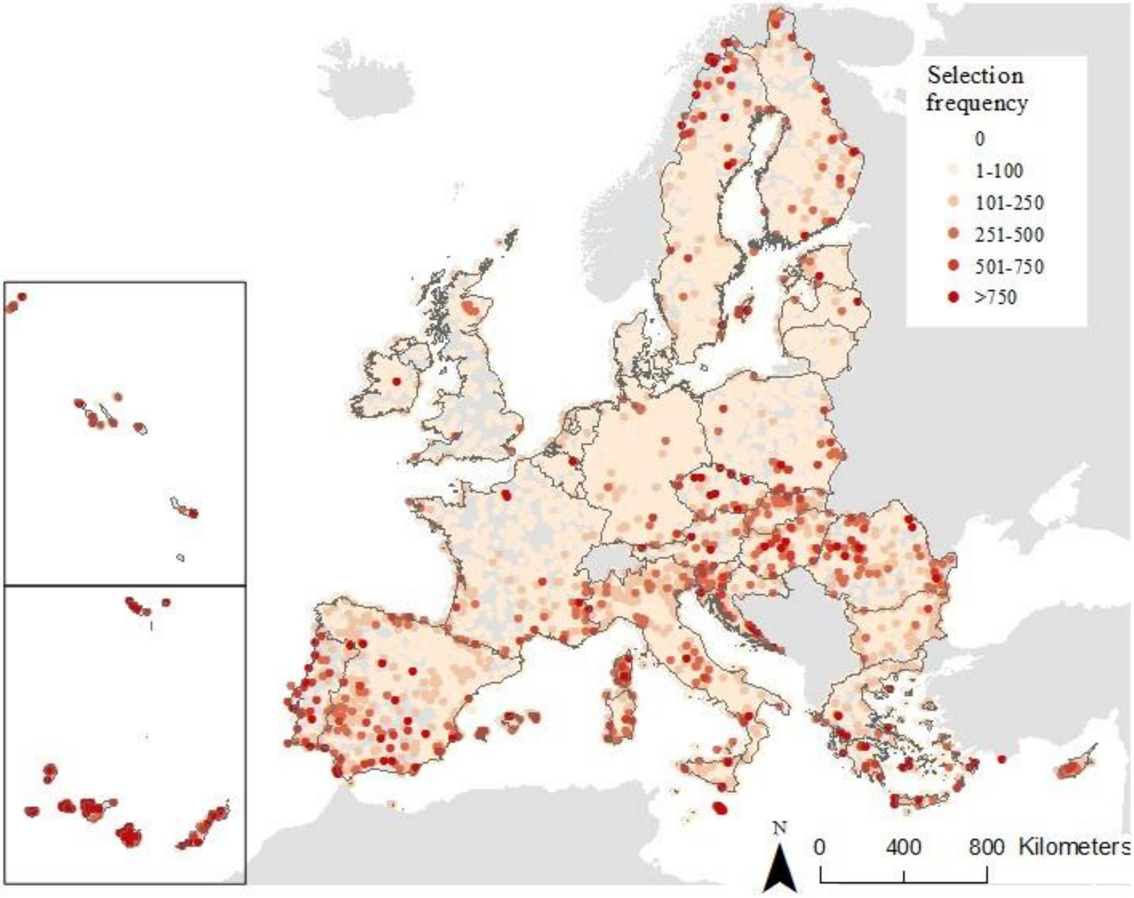
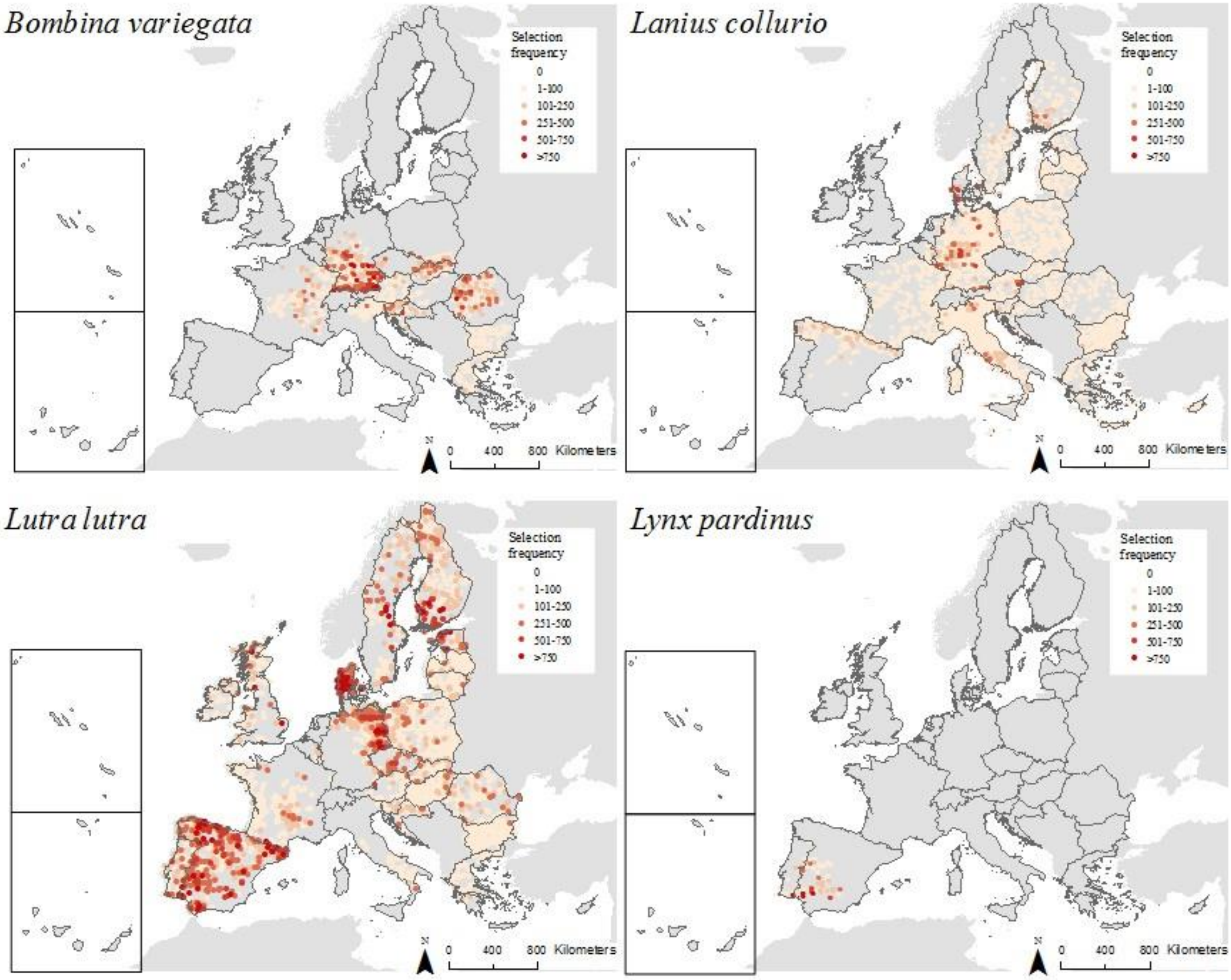

Selection frequency
0
1-100
101-250
251-500
501-750
>750
N
0
400
800 Kilometers

Figure 3


Bombina variegata
Selection frequency
0
1-100
101-250
251-500
501-750
>750
N
0 400 800 Kilometers
Lanius collurio
Selection frequency
0
1-100
101-250
251-500
501-750
>750
N
0 400 800 Kilometers
Lutra lutra
Selection frequency
0
1-100
101-250
251-500
501-750
>750
N
0 400 800 Kilometers
Lynx pardinus
Selection frequency
0
1-100
101-250
251-500
501-750
>750
N
0 400 800 Kilometers